JC10 Rec'd PCT/PTO 08 MAR 2002

(1390 REV. 5-93) US DEPT. OF COMMERCE PATENT & TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER 112161 U.S. APPLICATION NO. (if known, sec 37 C.F.R.1.5) 10/070682
INTERNATIONAL APPLICATION NO. PCT/JP00/06130	INTERNATIONAL FILING DATE September 8, 2000	PRIORITY DATE CLAIMED September 10, 1999
TITLE OF INVENTION EXPOSURE DEVICE WITH LASER DEVICE		
APPLICANT(S) FOR DO/EO/US Tomoko OHTSUKI		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ Entitlement to small entity status is hereby asserted.
16. ☐ Other items or information:

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JC19 Rec'd PCT/PTO 08 MAR 2002

U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) 10/070682	INTERNATIONAL APPLICATION NO. PCT/JP00/06130	ATTORNEY'S DOCKET NUMBER 112161

				CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **Basic National fee (37 CFR 1.492(a)(1)-(5)):** Search Report has been prepared by the EPO or JPO .... $890.00 International preliminary examination fee paid to USPTO (37 CFR1.482) .... $710.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $740.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $1,040.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) .... $ 100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	28 - 20 =	8	X $ 18.00	$144.00	
Independent Claims	9 - 3 =	6	X $ 84.00	$504.00	
Multiple dependent claim(s)(if applicable)			+ $280.00	$	
TOTAL OF ABOVE CALCULATIONS =				$1538.00	
Reduction by 1/2 for filing by small entity, if applicable. -				$	
SUBTOTAL =				$1538.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 month from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$1538.00	
				Amount to be refunded	$
				Charged	$

a. ☒ Check No. 128566 in the amount of $1538.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Director is hereby authorized to charge any additional fees which may be required, or credit any overpayment, to Deposit Account No. 15-0461. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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PATENT APPLICATION #5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Tomoko OHTSUKI

Application No.: 10/070,682

Filed: September 4, 2002 Docket No.: 112161

For: EXPOSURE APPARATUS WITH LASER DEVICE

SUPPLEMENTAL PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office
Washington, D. C. 20231

Sir:

Prior to initial examination, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Page 19, lines 19-27 and Page 20, line 1, delete current paragraph and insert therefor:

The exposure apparatus of the present invention further includes an illumination system which irradiates a mask with ultraviolet light from the laser device, and a projection optical system which projects an image of a pattern of the mask onto a substrate, wherein the substrate is exposed with the ultraviolet light passed through the pattern of the mask. With the laser device of the present invention being used, the exposure apparatus can be miniaturized overall, and the maintainability thereof is increased.

Page 22, lines 16-18, delete current paragraph and insert therefor:

Figs. 7A, 7B and 7C are diagrams showing waveforms of laser beams in individual portions of another example according to the present embodiment of the present invention.

Page 22, lines 19-23, delete current paragraph and insert therefor:

Fig. 8A is a diagram showing a first configuration example of a wavelength conversion section 20 shown in Figs. 1A and 1B, and Fig. 8B is a diagram showing a second configuration example of the wavelength conversion section 20.

Page 22, lines 24-25 and Page 23, lines 1-2, delete current paragraph and insert therefor:

Fig. 9A is a diagram showing a third configuration example of a wavelength conversion section 20, and Fig. 9B is a diagram showing a fourth configuration example of the wavelength conversion section 20.

Page 23, lines 18-26 and Page 24, lines 1-3, delete current paragraph and insert therefor:

Fig. 1A shows an ultraviolet light generator according to the present example. Referring to Fig. 1A, a single wavelength oscillatory laser 11, which is provided as a laser light generation section, generates a laser beam LB1 that is formed of a continuous wave (CW) having a narrow spectral width and that has a wavelength of 1.544 μm. The laser beam LB1 is incident on an optical modulating device 12, which is provided as an optical modulator, via an isolator IS1 provided for blocking reverse light. The laser beam LB1 is converted therein into a laser beam LB2 (pulsed beam), and the laser beam LB2 is then incident on an optical splitting amplifier section 4.

Page 27, lines 6-22, delete current paragraph and insert therefor:

Moreover, as shown in Fig. 1B, output terminals 19a of the fiber bundle 19 are bundled such that the m·n optical fibers (128 optical fibers in the present example) tightly contacts one another, and the outer shape thereof is circular in a cross-sectional view. In a practical configuration, however, the outer shape of the output terminals 19a and the number of optical fibers are determined according to, for example, the rear-stage configuration of the wavelength conversion section 20 and use conditions of the ultraviolet light generator of the

present example. The clad diameter of each of the optical fibers constituting the fiber bundle 19 is about 125 μm. Accordingly, when 128 optical fibers are bundled circular, a diameter d1 of each of the output terminals 19a can be set to about 2 mm or smaller. The configuration of the optical splitting amplifier section 4 is not limited to that shown in Figs. 1A and 1B. For example, a time division multiplexer may be used as an optical splitter.

Page 27, lines 8-24, delete current paragraph and insert therefor:

Moreover, as shown in Fig. 1B, output terminals 19a of the fiber bundle 19 are bundled such that the m·n optical fibers (128 optical fibers in the present example) tightly contacts one another, and the outer shape thereof is circular in a cross-sectional view. In a practical configuration, however, the outer shape of the output terminals 19a and the number of optical fibers are determined according to, for example, the rear-stage configuration of the wavelength conversion section 20 and use conditions of the ultraviolet light generator of the present example. The clad diameter of each of the optical fibers constituting the fiber bundle 19 is about 125 μm. Accordingly, when 128 optical fibers are bundled circular, a diameter d1 of each of the output terminals 19a can be set to about 2 mm or smaller. The configuration of the optical splitting amplifier section 4 is not limited to that shown in Figs. 1A and 1B. For example, a time division multiplexer may be used as an optical splitter.

Page 29, lines 19-27 and Page 30, lines 1-11, delete current paragraph and insert therefor:

Hereinbelow, the present embodiment will be described in further detail. Referring to Fig. 1A, for the single wavelength oscillatory laser 11 oscillating at a single wavelength, the present example uses, a laser, such as a distributed feedback (DFB) semiconductor laser. The DFB semiconductor laser is characterized by an InGaAsP construction, a 1.544 μm oscillation wavelength, and a 20 mW continuous output (which hereinbelow will be referred

to as "CW output"). In addition, the DFB semiconductor laser is configured such that, instead of a Fabry-Pelot resonator, a diffraction grating is formed in a semiconductor laser, in which single longitudinal mode oscillation is performed under any condition. Thus, since the DFB semiconductor laser performs the single longitudinal mode oscillation, the oscillation spectral linewidth can be controlled to be 0.01 pm or less. Alternatively, for the single wavelength oscillatory laser 11, the present example may be configured using a light source such as an erbium(Er)-doped fiber laser capable of generating a laser beam having a wavelength region similar to the above and a narrowed bandwidth.

Page 40, lines 24-27 and Page 41, lines 1-16, delete current paragraph and insert therefor:

Referring to Fig. 1A, the laser beams passed through the m-group delay fibers (optical fibers 17-1 to 17-n) are incident on the respective optical amplifier units 18-1 to 18-n, and are amplified thereby. The individual optical amplifier units 18-1 to 18-n of the present example have optical fiber amplifiers. However, as in the case of, particularly, the last-stage optical fiber amplifier, when high-intensity light propagates through the optical fibers, the wavelength width of the propagated light is expanded by influences of, for example, SPM (self phase modulation), SRS (stimulated raman scattering), and SBS (stimulated brillouin scattering), which are attributable to the optical-fiber nonlinear effects. Hereinbelow will be described an example configuration that mitigates the wavelength width expansion by reducing the influence of the nonlinear effects. While description given hereinbelow will cover several example configurations of an optical amplifier unit that may be used for the optical amplifier unit 18-1, the example configurations may similarly be used for the other optical amplifier units 18-2 to 18-n.

Page 42, lines 24-27 and Page 43, lines 1-9, delete current paragraph and insert therefor:

In the present example, the laser beam LB3 from the optical fiber 17-1 shown in Fig. 1A is led via the WDM device 21A to be incident on the amplifying optical fiber 22, and is amplified thereby. Then, the laser beam LB3 amplified by the amplifying optical fiber 22 is incident on the amplifying optical fiber 25 via the WDM device 21B, the narrow band filter 24A, the isolator IS3, and WDM device 21C; and the incident laser beam LB3 is thereby amplified again. Via the WDM device 21D, the amplified laser beam LB3 propagates through one of optical fibers that constitute the fiber bundle 19 shown in Fig. 1A(the aforementioned optical fiber may be an extended portion of an output terminal of the amplifying optical fiber 25).

Page 43, lines 10-24, delete current paragraph and insert therefor:

The total of amplification gains according to the second-stage optical fiber amplifiers 22 and 25 is 46 dB (39,810 times) as one example. When the total number of channels (m·n pieces) output from the splitters 16-1 to 16-m shown in Fig. 1B is 128, and the average output power of each of the channels is about 50 μm, the average output power of all the channels is about 6.4 mW. When a laser beam of each of the channel is amplified at about 46 dB, the average output power of the laser beam output from each of the optical amplifier units 18-1 to 18-n is about 2 W. When the above is assumed to have been pulsed at a pulsewidth of 1 ns, and a pulse frequency of 100 kHz, the peak output power of each of the laser beams is 20 kW. Also, the average output power of the laser beam Lb4 output from the fiber bundle 19 is about 256 W.

Page 43, lines 25-27 and Page 44, lines 1-11, delete current paragraph and insert therefor:

In the present example, coupling losses in the splitters 14 and 16-1 to 16-m shown in Fig. 1A are not taken into consideration. However, even when the coupling losses occur, the output powers of the laser beams of the individual channels can be unformed to be the above-

described value (for example, the peak output power of 20 kW). This can be achieved by increasing at least one of the amplification gains obtained according to the optical fiber amplifiers 22 and 25 by the amount of the loss. In addition, the value of the output power (output power of the fundamental wave) of the single wavelength oscillatory laser 11 shown in Fig. 1A can be controlled larger or smaller than the aforementioned value. This can be achieved by controlling the amplification gains obtained according to the optical fiber amplifiers 22 and 25.

Page 44, lines 12-27 and Page 45, line 1, delete current paragraph and insert therefor:

Referring to the example configuration shown in Fig. 2, the narrow band filter 24A removes ASE (amplified spontaneous emission) light occurring in each of the optical fiber amplifier 13 shown in Fig. 1A and the amplifying optical fiber 22 shown in Fig. 2, and lets the laser beam (having a wavelength width of 1 pm or less) output from the single wavelength oscillatory laser 11 shown in Fig. 1A to transmit. Thereby, the narrow band filter 24A substantially makes the wavelength width of the transmitted beam to be a narrow band. This enables the amplification gain of the laser beam to be prevented from being reduced by the incidence of the ASE light. In this case, the narrow band filter 24A preferably has a transmission wavelength width of about 1 pm. However, since the wavelength width of the ASE light is several tens of nm, the ASE light can be removed not to cause a problem in practice even by using a currently available narrow band filter with a transmission wavelength width of about 100 pm.

Page 45, lines 2-8, delete current paragraph and insert therefor:

Suppose the output wavelength of the single wavelength oscillatory laser 11 in Fig. 1A is positively changed. In this case, while the narrow band filter 24A may be replaced according to the output wavelength. However, preferably, a narrow band filter having a

transmission wavelength width (equivalent to a variable range (about ±20 pm, as mentioned above as an example, for an exposure apparatus) is used.

Page 49, lines 18-27 and Page 50, lines 1-12, delete current paragraph and insert therefor:

Hereinbelow, a fifth example configuration of an optical amplifier unit 18D will be described with reference to Fig. 6. Fig. 6 shows the configuration by using the same reference symbols for portions corresponding to those shown in Fig. 2; and detailed descriptions are omitted herefrom regarding the corresponding portions. The optical amplifier unit 18D shown in Fig. 6 is configured to include the coupling-dedicated WDM device 21C and the narrow band filter 24A that are coupled in the front and back of the optical fiber amplifier 25. In this configuration, an excitation beam EL3 from the semiconductor laser 23C is fed to the optical fiber amplifier 25 via the WDM device 21C. The narrow band filter 24A is shared as a coupling-dedicated wavelength division multiplexing device (WDM device). The excitation beam EL4 from the semiconductor laser 23D is fed to the optical fiber amplifier 25 via the narrow band filter 24A. In the present example, the output terminal of the narrow band filter 24A is coupled to an undoped optical fiber 26 that constitutes the fiber bundle 19 shown in Fig. 1A. The amplifying optical fiber 22 shown in Fig. 2 and an exciting member therefor (not shown) are coupled to a front stage of the WDM device 21C.

Page 50, lines 22-27 and Page 51, lines 1-11, delete current paragraph and insert therefor:

Hereinbelow, another example of the present embodiment according to the present invention will be described with reference to Figs. 1A, 1B, 2, 7A, 7B, and 7C. According to the above-described embodiment, the pulsewidth of the laser beam output from the optical modulating device 12 shown in Fig. 1A is set to about 1 ns. With the pulsewidth which is

thus short, when the peak output power is increased, an unexpected case can occur in which the frequency expansion is increased due to SPM (self phase modulation), particularly in the rear-stage optical fiber amplifier. As such, in the present example, the width of the output pulse in the optical modulating device 12 is set to a width that is several times a pulsewidth (about 1 ns in the present example) which is determined depending on the transfer limit in a required frequency width, for example, in a range of from 2 to 5 ns, and the pulse waveform is controlled to maximize the pulse transient time.

Page 51, lines 12-26, delete current paragraph and insert therefor:

Figs. 7A, 7B and 7C show example pulse waveforms in individual portions. Intensity variations with respect a time t of the laser beam LB2 output from the optical modulating device 12 shown in Fig. 1A are represented as a waveform 28A shown by a solid line in Fig. 7B. Fig. 7B shows that a pulsewidth ΔtA of the waveform 28A is set to a level of two times a pulsewidth ΔtB of a waveform 28B, shown by a dotted line, which is determined depending on the transfer limit in a desired frequency width. In this case, the laser beam LB1 output from the single wavelength oscillatory laser 11 shown in Fig. 1A may be a CW wave as shown by the solid line in Fig. 7A. However, when the laser beam LB1 is controlled to be a pulsed beam having a width larger than the pulsewidth ΔtA, as a waveform 27 shown by a double-dotted chain line, use efficiency of the laser beam can be improved.

Page 51, line 27 and Page 52, lines 1-11, delete current paragraph and insert therefor:

In addition, suppose the optical amplifier unit 18 shown in Fig. 2 is assumed to be used for the optical amplifier unit 18-1 shown in Fig. 1A. In this case, when the pulsewidth of the laser beam LB2 is increased as described above, while the SPM influence is reduced particularly in the last-stage optical fiber amplifier 25, the SBS (stimulated brillouin scattering) influence is increased. Nevertheless, however, bleaching of the gain occurs in the last-stage optical fiber amplifier 25. Hence, as shown by a solid line of waveform 29A in

Fig. 7C, the pulsewidth of the laser beam LB3 output from the optical amplifier unit 18 is reduced shorter than that of a waveform 29B that is shown by a dotted line and that corresponds as is to the laser beam LB2. Thereby, the adverse effect of the pulsewidth expanded in the optical modulating device 12 is reduced; and consequently, the wavelengths-in-width of ultraviolet lights to be finally output overall can be narrowed.

Page 52, lines 17-27 and Page 53, lines 1-9, delete current paragraph and insert therefor:

In the above-described embodiment, the laser light source having an oscillation wavelength of about 1.544 μm is used for the single wavelength oscillatory laser 11. Instead of this laser light source, however, the embodiment may use a laser light source having an oscillation wavelength in a range of from 1.099 to 1.106 μm. For this laser light source, either a DFB semiconductor laser or an ytterbium(Yb)-doped fiber laser may be used. In this case, for the optical fiber amplifier in the rear-stage optical amplification section, the configuration may use an ytterbium(Yb)-doped fiber (YDFA) that performs amplification in a wavelength zone of 990 to 1200 nm including the wavelength of the amplifier section. In this case, ultraviolet light having a wavelength of 157 to 158 nm wave that is substantially the same wavelength of the F_2 laser can be obtained by outputting the seventh-order harmonic wave in the wavelength conversion section 20 shown in Fig. 1B. In practice, ultraviolet light having substantially the same wavelength as that of the F_2 laser can be obtained by controlling the oscillation wavelength to be about 1.1 μm.

Page 57, lines 13-16, delete current paragraph and insert therefor:

Hereinbelow, a description will be made regarding example configurations of the wavelength conversion section 20 used in the ultraviolet light generator of the embodiment shown in Figs. 1A and 1B.

Page 57, lines 17-27 and Page 58, lines 1-20, delete current paragraph and insert therefor:

Fig. 8A shows the wavelength conversion section 20 that is capable of obtaining the eighth-order harmonic wave through repetition of the second-order harmonic wave generation. In Fig. 8A, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm (the frequency is represented by "ω") output from an output terminal 19a of an optical fiber bundle 19 is incident on a first-stage nonlinear optical crystal 502. The second-order harmonic wave generation is performed therein to generate the second-order harmonic wave having a twofold frequency 2ω (wavelength: 1/2 of 772 nm) of the frequency ω. The generated second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 503 through a lens 505. Similar to the above, through the second-order harmonic wave generation, there is generated fourth-order harmonic wave having a twofold frequency of the frequency 2ω of the incident wave, that is, a fourfold frequency 4ω (wavelength: 1/4 of 386 nm) with respect to the fundamental wave. The generated fourth-order harmonic wave is then transferred to a third-stage nonlinear optical crystal 504 through a lens 506. Similarly, through the second-order harmonic wave generation, there is generated eighth-order harmonic wave having a twofold frequency of the frequency 4ω of the incident wave, that is, an eightfold frequency 8ω (wavelength: 1/8 of 193 nm) with respect to the fundamental wave. The eighth-order harmonic wave is output as laser beam LB5. Thus, the example configuration performs wavelength modulations in the following order: fundamental wave (wavelength: 1.544 μm) → second-order harmonic wave (wavelength: 772 nm) → fourth-order harmonic wave (wavelength: 386 nm) → eighth-order harmonic wave (wavelength: 193 nm).

Page 59, lines 6-27 and Page 60, line 1, delete current paragraph and insert therefor:

Referring to Fig. 8A, a converging lens, which is effective for improving the incidence efficiency of laser beam LB4, is preferably provided between the fiber bundle 19 and the nonlinear optical crystal 502. In this case, each of the optical fibers constituting the fiber bundle 19 has a mode diameter (core diameter) of about 20 μm, and a region where the conversion efficiency in the nonlinear optical crystal has a size of about 200 μm. As such, a lens with a very low magnification of about 10× magnification may be provided in units of the optical fiber to converge the laser beam output from each of the optical fibers into the nonlinear optical crystal 502. This applies also to other example configurations described below.

Page 60, lines 2-21, delete current paragraph and insert therefor:

Fig. 8B shows a wavelength conversion section 20A that is capable of obtaining the eighth-order harmonic wave by combining the second-order harmonic wave generation and sum frequency generation. Referring to Fig. 8B, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm output from the output terminal 19a of the fiber bundle 19 is incident on a first-stage nonlinear optical crystal 507 formed of the LBO crystal and controlled by the NCPM method. In the crystal 507, there is generated the second-order harmonic wave (wavelength: 722 nm) according to the second-order harmonic wave generation. In addition, a part of the fundamental wave is transmitted as is through the nonlinear optical crystal 507. Both the fundamental wave and second-order harmonic wave in a linearly polarized state are transmitted trough a wavelength plate 508 (for example, a 1/2 wavelength plate), and only the fundamental wave is output in a 90-degree rotated direction of polarization. The fundamental wave and the second-order harmonic wave individually pass through a lens 509 and are incident on a second-stage nonlinear optical crystal 510.

Page 63, lines 4-23, delete current paragraph and insert therefor:

The configuration between the second-stage nonlinear optical crystal 510 and the fourth-stage nonlinear optical crystal 517 is not limited to that shown in Fig. 8B. This configuration may be arbitrarily arranged as long as it has the same optical path lengths for the sixth-order harmonic wave and the second-order harmonic wave to cause the sixth-order harmonic wave and the second-order harmonic wave to be incident on the fourth-stage nonlinear optical crystal 517. Moreover, for example, the third-stage and fourth-stage nonlinear optical crystals 514 and 517 may be disposed on the same optical axis of the second-stage nonlinear optical crystal 510. In this configuration, the third-stage nonlinear optical crystal 514 is used to convert only the third-order harmonic wave into the sixth-order harmonic wave according to the second-order harmonic wave generation, and the converted harmonic wave and the non-converted second-order harmonic wave together may be incident on the fourth-stage nonlinear optical crystal 517. This configuration avoids the necessity of using the dichroic mirrors 511 and 516.

Page 63, lines 24-27 and Page 64, lines 1-15, delete current paragraph and insert therefor:

For the individual wavelength conversion sections 20 and 20A shown in Figs. 8A and 8B, the average output power of the per-channel eighth-order harmonic waves (wavelength: 193 nm) were experimentally obtained. As described in the above-described embodiment, the output of the fundamental wave at each of the channel output terminal is characterized by a peak power of 20 kW, a pulsewidth of 1 ns, a pulse repetition frequency of 100 kHz, and an average output power of 2W. As a result, the per-channel average output powers of the eighth-order harmonic waves were 229 mW in the wavelength conversion section 20 shown in Fig. 8A, and 38.3 mW in the wavelength conversion section 20A shown in Fig. 8B. Accordingly, the average output powers from the bundle of all the 128 channels are 29 W in the wavelength conversion section 20, and 4.9 W in the wavelength conversion section 20A.

As such, in either of the wavelength conversion sections 20 and 20A, ultraviolet light having a wavelength of 193 nm beam, which is sufficient as an exposure-apparatus-dedicated light source can be provided.

Page 65, lines 14-23, delete current paragraph and insert therefor:

Hereinbelow, a description will be made regarding an example configuration of a wavelength modulator section that enables ultraviolet light having substantially the same wavelength as that of the F_2 laser (wavelength: 157 nm). To implement the above, as the wavelength conversion section 20, the configuration may be arranged to use a wavelength conversion section capable of generating the tenth-order harmonic wave with 1.57 μm wavelength of the fundamental wave generated in the single wavelength oscillatory laser 11 shown in Fig. 1A.

Page 65, lines 24-27 and Page 66, lines 1-12, delete current paragraph and insert therefor:

Fig. 9A shows a wavelength conversion section 20B that enables the tenth-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. 9B, the fundamental wave of the laser beam LB4, having a wavelength of 1.57 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 602 formed of the LBO crystal, and is converted into the second-order harmonic wave according to the second-order harmonic wave generation. The second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 604 formed of LBO via a lens 603, and is converted into the fourth-order harmonic wave according to the second-order harmonic wave generation; and a part of the second-order harmonic wave is transmitted therethrough without being converted.

Page 68, lines 14-27, delete current paragraph and insert therefor:

Fig. 9B shows a wavelength conversion section 20C that enables the seventh-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. 9B, the laser beam LB4 (fundamental wave), having a wavelength of 1.099 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 702 formed of the LBO crystal, and the second-order harmonic wave is generated therein according to the second-order harmonic wave generation. A part of the fundamental wave is transmitted as is therethrough. Both the fundamental wave and second-order harmonic wave transmits in a linearly polarized state transmits through a wavelength plate 703 (such as a 1/2 wavelength plate), and only the direction of polarization of only the fundamental wave is rotated through 90 degrees. The fundamental wave and the second-order harmonic wave is led through a lens 704 to be incident on a second nonlinear optical crystal 705 formed of the LBO crystal. The third-order harmonic wave is generated therein according to the sum frequency generation, and a part of the second-order harmonic wave is transmitted as is therethrough.

Page 70, lines 19-27 and Page 71, lines 1-10, delete current paragraph and insert therefor:

As is apparent from Fig. 1A, in the above-described embodiment, the combined light of the outputs of the n optical amplifier units 18-1 to 18-n in the m-group is converted in wavelength by using the single wavelength conversion section 20. Alternatively, however, the configuration may be arranged such that, for example, m' units (m' = "2" or larger inger) wavelength conversion sections are provided. In the alternative configuration, the outputs of the m-group optical amplifier units 18-1 to 18-n are divided in units of n' outputs into m' groups, the wavelength conversion is performed for one of the wavelength conversion section in units of one of the groups, and the obtained m' ultraviolet light beams (in the present

example, m' = "4", "5", or the like) are combined. Thus, the wavelength conversion section 20 is not limited to that having the above-described configuration. Moreover, for example, a CBO crystal (CsB_3O_5), a lithium tetraborate $Li_2B_4O_7$ (LBO), a KAB ($K_2Al_2B_4O_7$), or a GdYCOB ($Gd_XY_{1-x}Ca_4O(BO_3)_3$), may be used as an alternative crystal for the nonlinear optical crystal.

Page 71, lines 11-26, delete current paragraph and insert therefor:

According to the ultraviolet light generator of the above-described embodiment, the diameter of the output terminal of the fiber bundle 19, shown in Fig. 1A, even with all the channels being included, is about 2 mm or smaller. As such, one or several units of the wavelength conversion sections 20 are sufficient to perform the wavelength conversion of all the channels. In addition, since flexible optical fibers are used for the output terminals, the flexibility in configuration is very high. For example, the configuration sections such as the wavelength conversion section, the single wavelength oscillatory laser, and the splitter, can be separately disposed. Consequently, the ultraviolet light generator of the present example enables the provision of an ultraviolet laser device that is inexpensive and compact, and has a low spatial coherence while it is of a single wavelength type.

Page 71, line 27 and Page 72, lines 1-22, delete current paragraph and insert therefor:

Hereinbelow, an example exposure apparatus using the ultraviolet light generator shown in Fig. 1A will be described. Fig. 10 shows the exposure apparatus of the present example. Referring to Fig. 10, devices usable for an exposure light source 161 include, for example, a device with an ultraviolet region of 193 nm, 157 nm, or the like based on the wavelength of a laser beam that is output from the ultraviolet light generator shown in Fig. 1A. A laser beam LB5 that has been output from the exposure light source 161 is incident as exposure light IL on an illumination system 162. The illumination system 162 is configured of, for example, an optical integrator (homogenizer) for homogenizing illuminance

distributions of the exposure light IL, an aperture diaphragm, a field diaphragm (reticle blind), and a condenser lens. In the aforementioned configuration, the exposure light IL output from the illumination system 162 illuminates a slit-like illumination region of a pattern surface of a reticle 163 set as a mask to provide a homogeneous illuminance distribution. In the present example, since the spatial coherence of the exposure light IL is so low that the configuration of a member for reducing the spatial coherence in the illumination system 162 can be simplified, and the exposure apparatus can therefore be further miniaturized.

Page 74, lines 18-27 and Page 75, lines 1-15, delete current paragraph and insert therefor:

Exposure-light-amount control in the above-described scan-exposure operation may be implemented in the following manner. Control is performed for at least one of the pulse repetition frequency f, which is defined by the optical modulating device 12 shown in Fig. 1A, and the interchannel delay time, which is defined by the delaying devices (optical fibers 15-1 to 15-m, and 17-1 to 17-n). The control is thus performed to cause a fundamental-wave generator section 171 to oscillate a plurality of pulsed beams at equal time intervals during scan-exposure operation. In addition, according to the sensitivity property of the photoresist, at least one of the optical intensity of the pulsed beam on the wafer 166, the scan speed for the wafer 166, the pulsed-beam oscillation interval (frequency), and the width of the pulsed beam in the scan direction for the wafer 166 (that is, an radiation region thereof) to thereby control the integrated luminous quantity of a plurality of pulsed beams irradiated in a period in which the individual points of the wafer traverse the radiation region. At this time, in consideration of the throughput, least one of other control parameters representing the pulsed-beam optical intensity, the oscillation frequency, and the radiation region width is preferably controlled so that the scan speed for the wafer 166 is substantially maintained to be the maximum speed of the wafer stage 167.

Page 75, lines 16-27 and Page 76, lines 1-4, delete current paragraph and insert therefor:

Fig. 11 shows another exposure apparatus using the ultraviolet light generator of the present example. Referring to Fig. 11, the ultraviolet light generator shown in Fig. 1A is attached apart. Specifically, referring to Fig. 11 showing the portions corresponding to those shown in Fig. 10 by assigning the same reference symbols, a wavelength conversion section 172 corresponding to the wavelength conversion section 20 shown in Fig. 1A is mounted on the exposure apparatus mainbody. On the other hand, a light-source mainbody section 171 corresponding to the members of from the single wavelength oscillatory laser 11 to optical splitting amplifier section 4 shown in Fig. 1A are provided outside of the exposure apparatus mainbody, and a coupling-dedicated optical fiber 173 is used to couple therebetween. The coupling-dedicated optical fiber 173 corresponds to the fiber bundle 19 shown in Fig. 1A.

Page 78, lines 4-14, delete current paragraph and insert therefor:

In the present example, a laser beam from the light-source mainbody section 171 is fed to a wavelength conversion section 179 via an optical fiber 178. For the wavelength conversion section 179, the present example uses a wavelength conversion section that is similar to the wavelength conversion section 20 shown in Fig. 1A and that is relatively small. The wavelength conversion section 179 is integrally provided on the frame that holds the alignment system 180, in which ultraviolet light that has been output from the wavelength conversion section 179 is used as illumination light.

Page 79, lines 5-21, delete current paragraph and insert therefor:

The exposure apparatus of the above-described embodiment shown, for example, in Fig. 11, may include a spatial-image measuring system. The spatial-image measuring system may be such that the mark provided on the reticle 163 and the reference mark provided on the reticle stage 164 are illuminated with illumination light having the same wavelength, and a

mark image formed by the projection optical system 165 is detected through an opening (such as a slit) provided on the wafer stage 167. For a light source generating the illumination light for the spatial-image measuring system, a light source (similar to the ultraviolet light generator shown in Figs. 1A and 1B) having the same configuration as that of the above-described light source (171 and 179) may be separately provided. Alternatively, the exposure-dedicated light source formed of the members including the light-source mainbody section 171 and the illumination system 162 may be shared.

Page 79, lines 22-27 and Page 80, lines 1-10, delete current paragraph and insert therefor:

In the above-described embodiment, description has been made that the laser device shown in Figs. 1A and 1B is used either as the exposure-dedicated light source or as the light source of the alignment system or the spatial-image measuring system. However, the laser device may be used as a regulating light source of a detecting system or an optical system for marks other than the above. In addition, the laser device may be used not only as the light source of the exposure apparatus, the testing apparatus, or the like used in the device-manufacturing step, but also as a light source of various other apparatuses, regardless of the use and like thereof (an example is an apparatus using an excimer laser as a light source, such as a laser medical treatment apparatus for performing medical treatment for, for example, the near site and the astigmatism, by correcting, for example, the curvature or the irregularity of the cornea).

<u>IN THE CLAIMS</u>:

Please replace claims 14 and 22-24 as follows:

14. (Amended) An exposure apparatus as recited in claim 1, wherein the optical fiber amplification section is an erbium-doped fiber amplifier and uses laser light having a wavelength of (980±10) nm as the excitation light for the amplifier.

22. (Amended) An exposure apparatus as recited in claim 1, wherein

the laser light generation section generates single wavelength laser light having a wavelength of near 1.5 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.5 μm into ultraviolet light of an eighth-order harmonic wave or a tenth-order harmonic wave and outputs the converted light.

23. (Amended) An exposure apparatus as recited in claim 1, wherein

the laser light generation section generates a single wavelength laser light having a wavelength of near 1.1 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.1 μm into ultraviolet light of a seventh-order harmonic wave thereof and outputs the converted light.

24. (Amended) An exposure apparatus as recited in claim 1, comprising:

an illumination system which radiates ultraviolet light from the laser device onto a mask as the first object: and

a projection optical system which projects an image of a pattern of the mask onto a substrate as the second object.

REMARKS

Claims 1-28 are pending. By this Preliminary Amendment, the specification is amended and claims 14 and 22-24 are amended to correct inadvertent errors in the First Preliminary Amendment filed September 6, 2002. Prompt and favorable examination to the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. §1.121(b)(1)(iii)) and claim (37 C.F.R. §1.121(c)(1)(ii)).

Respectfully submitted,

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MAC:JSA/cmm

Attachment:
Appendix

Date: October 9, 2002

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DEPOSIT ACCOUNT USE AUTHORIZATION
Please grant any extension necessary for entry;
Charge any fee due to our Deposit Account No. 15-0461

APPENDIX

Changes to Specification:

Page 19, lines 19-27 and Page 20, line 1:

The exposure apparatus of the present invention further includes an illumination system ~~(162)~~ which irradiates a mask~~(163)~~ with ultraviolet light from the laser device, and a projection optical system ~~(165)~~ which projects an image of a pattern of the mask onto a substrate ~~(166)~~, wherein the substrate is exposed with the ultraviolet light passed through the pattern of the mask. With the laser device of the present invention being used, the exposure apparatus can be miniaturized overall, and the maintainability thereof is increased.

Page 22, lines 16-18:

~~Fig. 7 is a~~ Figs. 7A, 7B and 7C are diagrams showing waveforms of laser beams in individual portions of another example according to the present embodiment of the present invention.

Page 22, lines 19-23:

~~In Fig. 8, Fig. 8(a)~~ Fig. 8A is a diagram showing a first configuration example of a wavelength conversion section 20 shown in ~~Fig. 1~~ Figs. 1A and 1B, and ~~Fig. 8(b)~~ Fig. 8B is a diagram showing a second configuration example of the wavelength conversion section 20.

Page 22, lines 24-25 and Page 23, lines 1-2:

~~In Fig. 9, Fig. 9(a)~~ Fig. 9A is a diagram showing a third configuration example of a wavelength conversion section 20, and ~~Fig. 9(b)~~ Fig. 9B is a diagram showing a fourth configuration example of the wavelength conversion section 20.

Page 23, lines 18-26 and Page 24, lines 1-3:

Fig. ~~1(a)~~ 1A shows an ultraviolet light generator according to the present example. Referring to Fig. ~~1(a)~~ 1A, a single wavelength oscillatory laser 11, which is provided as a laser light generation section, generates a laser beam LB1 that is formed of a continuous

wave (CW) having a narrow spectral width and that has a wavelength of 1.544 μm. The laser beam LB1 is incident on an optical modulating device 12, which is provided as an optical modulator, via an isolator IS1 provided for blocking reverse light. The laser beam LB1 is converted therein into a laser beam LB2 (pulsed beam), and the laser beam LB2 is then incident on an optical splitting amplifier section 4.

Page 27, lines 6-22:

Moreover, as shown in Fig. ~~1(b)~~ 1B, output terminals 19a of the fiber bundle 19 are bundled such that the m·n optical fibers (128 optical fibers in the present example) tightly contacts one another, and the outer shape thereof is circular in a cross-sectional view. In a practical configuration, however, the outer shape of the output terminals 19a and the number of optical fibers are determined according to, for example, the rear-stage configuration of the wavelength conversion section 20 and use conditions of the ultraviolet light generator of the present example. The clad diameter of each of the optical fibers constituting the fiber bundle 19 is about 125 μm. Accordingly, when 128 optical fibers are bundled circular, a diameter d1 of each of the output terminals 19a can be set to about 2 mm or smaller. The configuration of the optical splitting amplifier section 4 is not limited to that shown in ~~Fig. 1~~ Figs. 1A and 1B. For example, a time division multiplexer may be used as an optical splitter.

Page 29, lines 19-27 and Page 30, lines 1-11:

Hereinbelow, the present embodiment will be described in further detail. Referring to Fig. ~~1 (a)~~ 1A, for the single wavelength oscillatory laser 11 oscillating at a single wavelength, the present example uses, a laser, such as a distributed feedback (DFB) semiconductor laser. The DFB semiconductor laser is characterized by an InGaAsP construction, a 1.544 μm oscillation wavelength, and a 20 mW continuous output (which hereinbelow will be referred to as "CW output"). In addition, the DFB semiconductor laser is configured such that, instead of a Fabry-Pelot resonator, a diffraction grating is formed in a semiconductor laser, in

which single longitudinal mode oscillation is performed under any condition. Thus, since the DFB semiconductor laser performs the single longitudinal mode oscillation, the oscillation spectral linewidth can be controlled to be 0.01 pm or less. Alternatively, for the single wavelength oscillatory laser 11, the present example may be configured using a light source such as an erbium(Er)-doped fiber laser capable of generating a laser beam having a wavelength region similar to the above and a narrowed bandwidth.

Page 40, lines 24-27 and Page 41, lines 1-16:

Referring to Fig. ~~1(a)~~ 1A, the laser beams passed through the m-group delay fibers (optical fibers 17-1 to 17-n) are incident on the respective optical amplifier units 18-1 to 18-n, and are amplified thereby. The individual optical amplifier units 18-1 to 18-n of the present example have optical fiber amplifiers. However, as in the case of, particularly, the last-stage optical fiber amplifier, when high-intensity light propagates through the optical fibers, the wavelength width of the propagated light is expanded by influences of, for example, SPM (self phase modulation), SRS (stimulated raman scattering), and SBS (stimulated brillouin scattering), which are attributable to the optical-fiber nonlinear effects. Hereinbelow will be described an example configuration that mitigates the wavelength width expansion by reducing the influence of the nonlinear effects. While description given hereinbelow will cover several example configurations of an optical amplifier unit that may be used for the optical amplifier unit 18-1, the example configurations may similarly be used for the other optical amplifier units 18-2 to 18-n.

Page 42, lines 24-27 and Page 43, lines 1-9:

In the present example, the laser beam LB3 from the optical fiber 17-1 shown in Fig. ~~1(a)~~ 1A is led via the WDM device 21A to be incident on the amplifying optical fiber 22, and is amplified thereby. Then, the laser beam LB3 amplified by the amplifying optical fiber 22 is incident on the amplifying optical fiber 25 via the WDM device 21B, the narrow band filter

24A, the isolator IS3, and WDM device 21C; and the incident laser beam LB3 is thereby amplified again. Via the WDM device 21D, the amplified laser beam LB3 propagates through one of optical fibers that constitute the fiber bundle 19 shown in Fig. ~~1(a)~~ 1A(the aforementioned optical fiber may be an extended portion of an output terminal of the amplifying optical fiber 25).

Page 43, lines 10-24:

The total of amplification gains according to the second-stage optical fiber amplifiers 22 and 25 is 46 dB (39,810 times) as one example. When the total number of channels (m·n pieces) output from the splitters 16-1 to 16-m shown in Fig. ~~1(b)~~ 1B is 128, and the average output power of each of the channels is about 50 μm, the average output power of all the channels is about 6.4 mW. When a laser beam of each of the channel is amplified at about 46 dB, the average output power of the laser beam output from each of the optical amplifier units 18-1 to 18-n is about 2 W. When the above is assumed to have been pulsed at a pulsewidth of 1 ns, and a pulse frequency of 100 kHz, the peak output power of each of the laser beams is 20 kW. Also, the average output power of the laser beam Lb4 output from the fiber bundle 19 is about 256 W.

Page 43, lines 25-27 and Page 44, lines 1-11:

In the present example, coupling losses in the splitters 14 and 16-1 to 16-m shown in Fig. ~~1(a)~~ 1A are not taken into consideration. However, even when the coupling losses occur, the output powers of the laser beams of the individual channels can be unformed to be the above-described value (for example, the peak output power of 20 kW). This can be achieved by increasing at least one of the amplification gains obtained according to the optical fiber amplifiers 22 and 25 by the amount of the loss. In addition, the value of the output power (output power of the fundamental wave) of the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A can be controlled larger or smaller than the aforementioned value. This can

be achieved by controlling the amplification gains obtained according to the optical fiber amplifiers 22 and 25.

Page 44, lines 12-27 and Page 45, line 1:

Referring to the example configuration shown in Fig. 2, the narrow band filter 24A removes ASE (amplified spontaneous emission) light occurring in each of the optical fiber amplifier 13 shown in Fig. ~~1(a)~~ 1A and the amplifying optical fiber 22 shown in Fig. 2, and lets the laser beam (having a wavelength width of 1 pm or less) output from the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A to transmit. Thereby, the narrow band filter 24A substantially makes the wavelength width of the transmitted beam to be a narrow band. This enables the amplification gain of the laser beam to be prevented from being reduced by the incidence of the ASE light. In this case, the narrow band filter 24A preferably has a transmission wavelength width of about 1 pm. However, since the wavelength width of the ASE light is several tens of nm, the ASE light can be removed not to cause a problem in practice even by using a currently available narrow band filter with a transmission wavelength width of about 100 pm.

Page 45, lines 2-8:

Suppose the output wavelength of the single wavelength oscillatory laser 11 in Fig. ~~1(a)~~ 1A is positively changed. In this case, while the narrow band filter 24A may be replaced according to the output wavelength. However, preferably, a narrow band filter having a transmission wavelength width (equivalent to a variable range (about ±20 pm, as mentioned above as an example, for an exposure apparatus) is used.

Page 49, lines 18-27 and Page 50, lines 1-12:

Hereinbelow, a fifth example configuration of an optical amplifier unit 18D will be described with reference to Fig. 6. Fig. 6 shows the configuration by using the same reference symbols for portions corresponding to those shown in Fig. 2; and detailed

descriptions are omitted herefrom regarding the corresponding portions. The optical amplifier unit 18D shown in Fig. 6 is configured to include the coupling-dedicated WDM device 21C and the narrow band filter 24A that are coupled in the front and back of the optical fiber amplifier 25. In this configuration, an excitation beam EL3 from the semiconductor laser 23C is fed to the optical fiber amplifier 25 via the WDM device 21C. The narrow band filter 24A is shared as a coupling-dedicated wavelength division multiplexing device (WDM device). The excitation beam EL4 from the semiconductor laser 23D is fed to the optical fiber amplifier 25 via the narrow band filter 24A. In the present example, the output terminal of the narrow band filter 24A is coupled to an undoped optical fiber 26 that constitutes the fiber bundle 19 shown in Fig. ~~1(a)~~ 1A. The amplifying optical fiber 22 shown in Fig. 2 and an exciting member therefor (not shown) are coupled to a front stage of the WDM device 21C.

Page 50, lines 22-27 and Page 51, lines 1-11:

Hereinbelow, another example of the present embodiment according to the present invention will be described with reference to Figs. ~~1~~ 1A, 1B, 2, ~~and 7~~ 7A, 7B, and 7C. According to the above-described embodiment, the pulsewidth of the laser beam output from the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A is set to about 1 ns. With the pulsewidth which is thus short, when the peak output power is increased, an unexpected case can occur in which the frequency expansion is increased due to SPM (self phase modulation), particularly in the rear-stage optical fiber amplifier. As such, in the present example, the width of the output pulse in the optical modulating device 12 is set to a width that is several times a pulsewidth (about 1 ns in the present example) which is determined depending on the transfer limit in a required frequency width, for example, in a range of from 2 to 5 ns, and the pulse waveform is controlled to maximize the pulse transient time.

Page 51, lines 12-26:

~~Fig. 7 shows~~ Figs. 7A, 7B and 7C show example pulse waveforms in individual portions. Intensity variations with respect a time t of the laser beam LB2 output from the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A are represented as a waveform 28A shown by a solid line in Fig. ~~7(b)~~ 7B. Fig. ~~7(b)~~ 7B shows that a pulsewidth ΔtA of the waveform 28A is set to a level of two times a pulsewidth ΔtB of a waveform 28B, shown by a dotted line, which is determined depending on the transfer limit in a desired frequency width. In this case, the laser beam LB1 output from the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A may be a CW wave as shown by the solid line in Fig. ~~7(a)~~ 7A. However, when the laser beam LB1 is controlled to be a pulsed beam having a width larger than the pulsewidth ΔtA, as a waveform 27 shown by a double-dotted chain line, use efficiency of the laser beam can be improved.

Page 51, line 27 and Page 52, lines 1-11:

In addition, suppose the optical amplifier unit 18 shown in Fig. 2 is assumed to be used for the optical amplifier unit 18-1 shown in Fig. ~~1(a)~~ 1A. In this case, when the pulsewidth of the laser beam LB2 is increased as described above, while the SPM influence is reduced particularly in the last-stage optical fiber amplifier 25, the SBS (stimulated brillouin scattering) influence is increased. Nevertheless, however, bleaching of the gain occurs in the last-stage optical fiber amplifier 25. Hence, as shown by a solid line of waveform 29A in Fig. ~~7(c)~~ 7C, the pulsewidth of the laser beam LB3 output from the optical amplifier unit 18 is reduced shorter than that of a waveform 29B that is shown by a dotted line and that corresponds as is to the laser beam LB2. Thereby, the adverse effect of the pulsewidth expanded in the optical modulating device 12 is reduced; and consequently, the wavelengths-in-width of ultraviolet lights to be finally output overall can be narrowed.

Page 52, lines 17-27 and Page 53, lines 1-9:

In the above-described embodiment, the laser light source having an oscillation wavelength of about 1.544 μm is used for the single wavelength oscillatory laser 11. Instead of this laser light source, however, the embodiment may use a laser light source having an oscillation wavelength in a range of from 1.099 to 1.106 μm. For this laser light source, either a DFB semiconductor laser or an ytterbium(Yb)-doped fiber laser may be used. In this case, for the optical fiber amplifier in the rear-stage optical amplification section, the configuration may use an ytterbium(Yb)-doped fiber (YDFA) that performs amplification in a wavelength zone of 990 to 1200 nm including the wavelength of the amplifier section. In this case, ultraviolet light having a wavelength of 157 to 158 nm wave that is substantially the same wavelength of the F_2 laser can be obtained by outputting the seventh-order harmonic wave in the wavelength conversion section 20 shown in Fig. ~~1(b)~~ 1B. In practice, ultraviolet light having substantially the same wavelength as that of the F_2 laser can be obtained by controlling the oscillation wavelength to be about 1.1 μm.

Page 57, lines 13-16:

Hereinbelow, a description will be made regarding example configurations of the wavelength conversion section 20 used in the ultraviolet light generator of the embodiment shown in ~~Fig. 1~~ Figs. 1A and 1B.

Page 57, lines 17-27 and Page 58, lines 1-20:

Fig. ~~8(a)~~ 8A shows the wavelength conversion section 20 that is capable of obtaining the eighth-order harmonic wave through repetition of the second-order harmonic wave generation. In Fig. ~~8(a)~~ 8A, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm (the frequency is represented by "ω") output from an output terminal 19a of an optical fiber bundle 19 is incident on a first-stage nonlinear optical crystal 502. The second-order harmonic wave generation is performed therein to generate the second-order

harmonic wave having a twofold frequency 2ω (wavelength: 1/2 of 772 nm) of the frequency ω. The generated second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 503 through a lens 505. Similar to the above, through the second-order harmonic wave generation, there is generated fourth-order harmonic wave having a twofold frequency of the frequency 2ω of the incident wave, that is, a fourfold frequency 4ω (wavelength: 1/4 of 386 nm) with respect to the fundamental wave. The generated fourth-order harmonic wave is then transferred to a third-stage nonlinear optical crystal 504 through a lens 506. Similarly, through the second-order harmonic wave generation, there is generated eighth-order harmonic wave having a twofold frequency of the frequency 4ω of the incident wave, that is, an eightfold frequency 8ω (wavelength: 1/8 of 193 nm) with respect to the fundamental wave. The eighth-order harmonic wave is output as laser beam LB5. Thus, the example configuration performs wavelength modulations in the following order: fundamental wave (wavelength: 1.544 μm) → second-order harmonic wave (wavelength: 772 nm) → fourth-order harmonic wave (wavelength: 386 nm) → eighth-order harmonic wave (wavelength: 193 nm).

Page 59, lines 16-27 and Page 60, line 1:

Referring to Fig. ~~8(a)~~ <u>8A</u>, a converging lens, which is effective for improving the incidence efficiency of laser beam LB4, is preferably provided between the fiber bundle 19 and the nonlinear optical crystal 502. In this case, each of the optical fibers constituting the fiber bundle 19 has a mode diameter (core diameter) of about 20 μm, and a region where the conversion efficiency in the nonlinear optical crystal has a size of about 200 μm. As such, a lens with a very low magnification of about 10× magnification may be provided in units of the optical fiber to converge the laser beam output from each of the optical fibers into the nonlinear optical crystal 502. This applies also to other example configurations described below.

Page 60, lines 2-21:

Fig. ~~8(b)~~ 8B shows a wavelength conversion section 20A that is capable of obtaining the eighth-order harmonic wave by combining the second-order harmonic wave generation and sum frequency generation. Referring to Fig. ~~8(b)~~ 8B, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm output from the output terminal 19a of the fiber bundle 19 is incident on a first-stage nonlinear optical crystal 507 formed of the LBO crystal and controlled by the NCPM method. In the crystal 507, there is generated the second-order harmonic wave (wavelength: 722 nm) according to the second-order harmonic wave generation. In addition, a part of the fundamental wave is transmitted as is through the nonlinear optical crystal 507. Both the fundamental wave and second-order harmonic wave in a linearly polarized state are transmitted trough a wavelength plate 508 (for example, a 1/2 wavelength plate), and only the fundamental wave is output in a 90-degree rotated direction of polarization. The fundamental wave and the second-order harmonic wave individually pass through a lens 509 and are incident on a second-stage nonlinear optical crystal 510.

Page 63, lines 4-23:

The configuration between the second-stage nonlinear optical crystal 510 and the fourth-stage nonlinear optical crystal 517 is not limited to that shown in Fig. ~~8(b)~~ 8B. This configuration may be arbitrarily arranged as long as it has the same optical path lengths for the sixth-order harmonic wave and the second-order harmonic wave to cause the sixth-order harmonic wave and the second-order harmonic wave to be incident on the fourth-stage nonlinear optical crystal 517. Moreover, for example, the third-stage and fourth-stage nonlinear optical crystals 514 and 517 may be disposed on the same optical axis of the second-stage nonlinear optical crystal 510. In this configuration, the third-stage nonlinear optical crystal 514 is used to convert only the third-order harmonic wave into the sixth-order

harmonic wave according to the second-order harmonic wave generation, and the converted harmonic wave and the non-converted second-order harmonic wave together may be incident on the fourth-stage nonlinear optical crystal 517. This configuration avoids the necessity of using the dichroic mirrors 511 and 516.

Page 63, lines 24-27 and Page 64, lines 1-15:

For the individual wavelength conversion sections 20 and 20A shown in ~~Fig. 8(a) and (b)~~ Figs. 8A and 8B, the average output power of the per-channel eighth-order harmonic waves (wavelength: 193 nm) were experimentally obtained. As described in the above-described embodiment, the output of the fundamental wave at each of the channel output terminal is characterized by a peak power of 20 kW, a pulsewidth of 1 ns, a pulse repetition frequency of 100 kHz, and an average output power of 2W. As a result, the per-channel average output powers of the eighth-order harmonic waves were 229 mW in the wavelength conversion section 20 shown in Fig. ~~8(a)~~ 8A, and 38.3 mW in the wavelength conversion section 20A shown in Fig. ~~8(b)~~ 8B. Accordingly, the average output powers from the bundle of all the 128 channels are 29 W in the wavelength conversion section 20, and 4.9 W in the wavelength conversion section 20A. As such, in either of the wavelength conversion sections 20 and 20A, ultraviolet light having a wavelength of 193 nm beam, which is sufficient as an exposure-apparatus-dedicated light source can be provided.

Page 65, lines 14-23:

Hereinbelow, a description will be made regarding an example configuration of a wavelength modulator section that enables ultraviolet light having substantially the same wavelength as that of the F_2 laser (wavelength: 157 nm). To implement the above, as the wavelength conversion section 20, the configuration may be arranged to use a wavelength conversion section capable of generating the tenth-order harmonic wave with 1.57 μm

wavelength of the fundamental wave generated in the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A.

Page 65, lines 24-27 and Page 66, lines 1-12:

Fig. ~~9(a)~~ 9A shows a wavelength conversion section 20B that enables the tenth-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. ~~9(b)~~ 9B, the fundamental wave of the laser beam LB4, having a wavelength of 1.57 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 602 formed of the LBO crystal, and is converted into the second-order harmonic wave according to the second-order harmonic wave generation. The second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 604 formed of LBO via a lens 603, and is converted into the fourth-order harmonic wave according to the second-order harmonic wave generation; and a part of the second-order harmonic wave is transmitted therethrough without being converted.

Page 68, lines 14-27:

Fig. ~~9(b)~~ 9B shows a wavelength conversion section 20C that enables the seventh-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. ~~9(b)~~ 9B, the laser beam LB4 (fundamental wave), having a wavelength of 1.099 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 702 formed of the LBO crystal, and the second-order harmonic wave is generated therein according to the second-order harmonic wave generation. A part of the fundamental wave is transmitted as is therethrough. Both the fundamental wave and second-order harmonic wave transmits in a linearly polarized state transmits through a wavelength plate 703 (such as a 1/2 wavelength plate), and only the direction of polarization of only the fundamental wave is

rotated through 90 degrees. The fundamental wave and the second-order harmonic wave is led through a lens 704 to be incident on a second nonlinear optical crystal 705 formed of the LBO crystal. The third-order harmonic wave is generated therein according to the sum frequency generation, and a part of the second-order harmonic wave is transmitted as is therethrough.

Page 70, lines 19-27 and Page 71, lines 1-10:

As is apparent from Fig. ~~1(a)~~ 1A, in the above-described embodiment, the combined light of the outputs of the n optical amplifier units 18-1 to 18-n in the m-group is converted in wavelength by using the single wavelength conversion section 20. Alternatively, however, the configuration may be arranged such that, for example, m' units (m' = "2" or larger inger) wavelength conversion sections are provided. In the alternative configuration, the outputs of the m-group optical amplifier units 18-1 to 18-n are divided in units of n' outputs into m' groups, the wavelength conversion is performed for one of the wavelength conversion section in units of one of the groups, and the obtained m' ultraviolet light beams (in the present example, m' = "4", "5", or the like) are combined. Thus, the wavelength conversion section 20 is not limited to that having the above-described configuration. Moreover, for example, a CBO crystal (CsB_3O_5), a lithium tetraborate $Li_2B_4O_7$ (LBO), a KAB ($K_2Al_2B_4O_7$), or a GdYCOB ($Gd_XY_{1-x}Ca_4O(BO_3)_3$), may be used as an alternative crystal for the nonlinear optical crystal.

Page 71, lines 11-26:

According to the ultraviolet light generator of the above-described embodiment, the diameter of the output terminal of the fiber bundle 19, shown in Fig. ~~1(a)~~ 1A, even with all the channels being included, is about 2 mm or smaller. As such, one or several units of the wavelength conversion sections 20 are sufficient to perform the wavelength conversion of all the channels. In addition, since flexible optical fibers are used for the output terminals, the

flexibility in configuration is very high. For example, the configuration sections such as the wavelength conversion section, the single wavelength oscillatory laser, and the splitter, can be separately disposed. Consequently, the ultraviolet light generator of the present example enables the provision of an ultraviolet laser device that is inexpensive and compact, and has a low spatial coherence while it is of a single wavelength type.

Page 71, line 27 and Page 72, lines 1-22:

Hereinbelow, an example exposure apparatus using the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A will be described. Fig. 10 shows the exposure apparatus of the present example. Referring to Fig. 10, devices usable for an exposure light source 161 include, for example, a device with an ultraviolet region of 193 nm, 157 nm, or the like based on the wavelength of a laser beam that is output from the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A. A laser beam LB5 that has been output from the exposure light source 161 is incident as exposure light IL on an illumination system 162. The illumination system 162 is configured of, for example, an optical integrator (homogenizer) for homogenizing illuminance distributions of the exposure light IL, an aperture diaphragm, a field diaphragm (reticle blind), and a condenser lens. In the aforementioned configuration, the exposure light IL output from the illumination system 162 illuminates a slit-like illumination region of a pattern surface of a reticle 163 set as a mask to provide a homogeneous illuminance distribution. In the present example, since the spatial coherence of the exposure light IL is so low that the configuration of a member for reducing the spatial coherence in the illumination system 162 can be simplified, and the exposure apparatus can therefore be further miniaturized.

Page 74, lines 18-27 and Page 75, lines 1-15:

Exposure-light-amount control in the above-described scan-exposure operation may be implemented in the following manner. Control is performed for at least one of the pulse

repetition frequency f, which is defined by the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A, and the interchannel delay time, which is defined by the delaying devices (optical fibers 15-1 to 15-m, and 17-1 to 17-n). The control is thus performed to cause a fundamental-wave generator section 171 to oscillate a plurality of pulsed beams at equal time intervals during scan-exposure operation. In addition, according to the sensitivity property of the photoresist, at least one of the optical intensity of the pulsed beam on the wafer 166, the scan speed for the wafer 166, the pulsed-beam oscillation interval (frequency), and the width of the pulsed beam in the scan direction for the wafer 166 (that is, an radiation region thereof) to thereby control the integrated luminous quantity of a plurality of pulsed beams irradiated in a period in which the individual points of the wafer traverse the radiation region. At this time, in consideration of the throughput, least one of other control parameters representing the pulsed-beam optical intensity, the oscillation frequency, and the radiation region width is preferably controlled so that the scan speed for the wafer 166 is substantially maintained to be the maximum speed of the wafer stage 167.

Page 75, lines 16-27 and Page 76, lines 1-4:

Fig. 11 shows another exposure apparatus using the ultraviolet light generator of the present example. Referring to Fig. 11, the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A is attached apart. Specifically, referring to Fig. 11 showing the portions corresponding to those shown in Fig. 10 by assigning the same reference symbols, a wavelength conversion section 172 corresponding to the wavelength conversion section 20 shown in Fig. ~~1(a)~~ 1A is mounted on the exposure apparatus mainbody. On the other hand, a light-source mainbody section 171 corresponding to the members of from the single wavelength oscillatory laser 11 to optical splitting amplifier section 4 shown in Fig. ~~1(a)~~ 1A are provided outside of the exposure apparatus mainbody, and a coupling-dedicated optical fiber 173 is used to couple

therebetween. The coupling-dedicated optical fiber 173 corresponds to the fiber bundle 19 shown in Fig. ~~1(a)~~ 1A.

Page 78, lines 4-14:

In the present example, a laser beam from the light-source mainbody section 171 is fed to a wavelength conversion section 179 via an optical fiber 178. For the wavelength conversion section 179, the present example uses a wavelength conversion section that is similar to the wavelength conversion section 20 shown in Fig. ~~1(a)~~ 1A and that is relatively small. The wavelength conversion section 179 is integrally provided on the frame that holds the alignment system 180, in which ultraviolet light that has been output from the wavelength conversion section 179 is used as illumination light.

Page 79, lines 5-21:

The exposure apparatus of the above-described embodiment shown, for example, in Fig. 11, may include a spatial-image measuring system. The spatial-image measuring system may be such that the mark provided on the reticle 163 and the reference mark provided on the reticle stage 164 are illuminated with illumination light having the same wavelength, and a mark image formed by the projection optical system 165 is detected through an opening (such as a slit) provided on the wafer stage 167. For a light source generating the illumination light for the spatial-image measuring system, a light source (similar to the ultraviolet light generator shown in ~~Fig. 1~~ Figs. 1A and 1B) having the same configuration as that of the above-described light source (171 and 179) may be separately provided. Alternatively, the exposure-dedicated light source formed of the members including the light-source mainbody section 171 and the illumination system 162 may be shared.

Page 79, lines 22-27 and Page 80, lines 1-10:

In the above-described embodiment, description has been made that the laser device shown in ~~Fig. 1~~ Figs. 1A and 1B is used either as the exposure-dedicated light source or as

the light source of the alignment system or the spatial-image measuring system. However, the laser device may be used as a regulating light source of a detecting system or an optical system for marks other than the above. In addition, the laser device may be used not only as the light source of the exposure apparatus, the testing apparatus, or the like used in the device-manufacturing step, but also as a light source of various other apparatuses, regardless of the use and like thereof (an example is an apparatus using an excimer laser as a light source, such as a laser medical treatment apparatus for performing medical treatment for, for example, the near site and the astigmatism, by correcting, for example, the curvature or the irregularity of the cornea).

Changes to Claims:

14. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11~~, ~~characterized in that~~ wherein the optical fiber amplification section is an erbium-doped fiber amplifier and uses laser light having a wavelength of (980±10) nm as the excitation light for the amplifier.

22. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized in that~~ wherein

the laser light generation section generates single wavelength laser light having a wavelength of near 1.5 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.5 μm into ultraviolet light of an eighth-order harmonic wave or a tenth-order harmonic wave and outputs the converted light.

23. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized in that~~ wherein

the laser light generation section generates a single wavelength laser light having a wavelength of near 1.1 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.1 μm into ultraviolet light of a seventh-order harmonic wave thereof and outputs the converted light.

24. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized by~~ comprising:

an illumination system which radiates ultraviolet light from the laser device onto a mask as the first object: and

 #4

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Tomoko OHTSUKI

Application No.: 10/070,682

Filed: September 4, 2002 Docket No.: 112161

For: EXPOSURE APPARATUS WITH LASER DEVICE

PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office
Washington, D. C. 20231

Sir:

Prior to initial examination, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Page 1, before line 1, insert a new paragraph as follows:

-- This application is the national phase under 35 U.S.C. 371 of prior PCT International Application No. PCT/JP00/06130 which has an International filing date of September 8, 2000 which designated the United States of America, the entire contents of which are hereby incorporated by reference. --

Page 7, lines 21-27 and Page 8, lines 1-9, delete current paragraph and insert therefor:

A first exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section including

plural stages of optical fiber amplifiers which serially amplifies the laser light generated by the laser light generation section, and a narrow band filter and an isolator between the plural stages of the optical fiber amplifiers; and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 8, lines 16-27 and Page 9, lines 1-8, delete current paragraph and insert therefor:

A second exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light output from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section including plural stages of amplifying optical fibers which amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates a plurality of amplifying excitation light beams, a narrow band filter or an isolator disposed between the plurality of the amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 9, lines 9-27 and Page 10, line 1, delete current paragraph and insert therefor:

A third exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification

section including plural stages of optical fiber amplifiers which amplify the laser light generated by the laser light generation section, a plurality of excitation-light generating light sources which individually generate excitation light for each of the plural stages of the amplifying optical fibers, and a narrow band filter, a reflection film which reflects the excitation light being formed at one of each of the optical fibers coupled to both sides of the narrow band filter; and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 10, lines 2-22, delete current paragraph and insert therefor:

A fourth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical modulation section which modulates the laser light generated by the laser light generation section with a predetermined repetition frequency into pulsed light having a predetermined width; an optical amplification section including an optical fiber amplifier which amplifies the laser light which has passed through the optical modulation section; and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal, the width of the pulsed light modulated by the optical modulation section is set wider than a pulsewidth set for obtaining a predetermined wavelength width with finally generated ultraviolet light.

Page 10, lines 23-27 and Page 11, lines 1-13, delete current paragraph and insert therefor:

A fifth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section including an optical fiber amplifier which amplifies the laser light generated by the laser light generation section, a transmitting optical fiber which propagates the laser light amplified by the optical fiber amplifier, and a narrow band filter disposed between the optical fiber amplifier and the transmitting optical fiber; and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 11, lines 14-27 and Page 12, lines 1-3, delete current paragraph and insert therefor:

A sixth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, an optical splitter which splits the laser light into a plurality of laser light beams, a plurality of optical fiber amplifiers which respectively and independently amplify the plurality of split laser light beams, a wavelength conversion section which performs wavelength conversion of the amplified laser light beams, and the laser device includes a regulator which regulates an amplification gain at at least one of the plurality of the optical fiber amplifiers so that outputs of the plurality of amplified laser light beams are substantially uniformalized.

Page 17, lines 14-27 and Page 18, lines 1-3, delete current paragraph and insert therefor:

Preferably, each of the above-described laser devices is configured to further include an optical splitter which splits the laser light generated by the laser light generation section into a plurality of laser light beams, and, in this configuration, optical amplification sections are independently provided for the plurality of split laser beams respectively, and the wavelength conversion section collects fluxes of laser beams output from the plurality of optical amplification sections and performs wavelength conversion thereof. Thus, the laser light split by the optical splitters are sequentially imparted with predetermined differences in optical path lengths and therefore, the spatial coherence of the laser light finally bundled can be reduced. Moreover, since each of the laser light beams is generated by the common laser light generation section, the spectral linewidth of the finally obtained ultraviolet light is narrow.

Page 19, lines 19-27 and Page 20, line 1, delete current paragraph and insert therefor:

The exposure apparatus of the present invention further includes an illumination system which irradiates a maskwith ultraviolet light from the laser device, and a projection optical system which projects an image of a pattern of the mask onto a substrate, wherein the substrate is exposed with the ultraviolet light passed through the pattern of the mask. With the laser device of the present invention being used, the exposure apparatus can be miniaturized overall, and the maintainability thereof is increased.

Page 20, lines 9-27, delete current paragraph and insert therefor:

Hereinbelow, a first exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which expose a second object with the ultraviolet light which has passed through the pattern of the first object,

wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, an optical amplification section including a narrow band filter and an isolator between the plural stages of optical fiber amplifiers, and a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 21, lines 1-23, delete current paragraph and insert therefor:

A second exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section including plurality of amplifying optical fibers which amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates a plurality of amplifying excitation light beams, a narrow band filter or an isolator disposed between the plurality of amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section for performing wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 22, lines 2-4, delete current paragraph and insert therefor:

Figs. 1A and 1B are diagrams showing an example of an ultraviolet light generator according to an embodiment of the present invention.

Page 22, lines 5-7, delete current paragraph and insert therefor:

Fig. 2 is a diagram showing a first configuration example of optical amplifier units 18-1 to 18-n shown in Figs. 1A and 1B.

Page 22, lines 16-19, delete current paragraph and insert therefor:

Figs. 7A, 7B and 7C are diagrams showing waveforms of laser beams in individual portions of another example according to the present embodiment of the present invention.

Page 22, lines 20-24, delete current paragraph and insert therefor:

Fig. 8A is a diagram showing a first configuration example of a wavelength conversion section 20 shown in Figs. 1A and 1B, and Fig. 8B is a diagram showing a second configuration example of the wavelength conversion section 20.

Page 22, line 25 and Page 23, lines 1-4, delete current paragraph and insert therefor:

Fig. 9A is a diagram showing a third configuration example of a wavelength conversion section 20, and Fig. 9B is a diagram showing a fourth configuration example of the wavelength conversion section 20.

Page 23, lines 21-17 and Page 24, lines 1-3, delete current paragraph and insert therefor:

Fig. 1A shows an ultraviolet light generator according to the present example. Referring to Fig. 1A, a single wavelength oscillatory laser 11, which is provided as a laser light generation section, generates a laser beam LB1 that is formed of a continuous wave (CW) having a narrow spectral width and that has a wavelength of 1.544 μm. The laser beam LB1 is incident on an optical modulating device 12, which is provided as an optical modulator, via an isolator IS1 provided for blocking reverse light. The laser beam LB1 is

converted therein into a laser beam LB2 (pulsed beam), and the laser beam LB2 is then incident on an optical splitting amplifier section 4.

Page 27, lines 8-24, delete current paragraph and insert therefor:

Moreover, as shown in Fig. 1B, output terminals 19a of the fiber bundle 19 are bundled such that the m·n optical fibers (128 optical fibers in the present example) tightly contacts one another, and the outer shape thereof is circular in a cross-sectional view. In a practical configuration, however, the outer shape of the output terminals 19a and the number of optical fibers are determined according to, for example, the rear-stage configuration of the wavelength conversion section 20 and use conditions of the ultraviolet light generator of the present example. The clad diameter of each of the optical fibers constituting the fiber bundle 19 is about 125 μm. Accordingly, when 128 optical fibers are bundled circular, a diameter d1 of each of the output terminals 19a can be set to about 2 mm or smaller. The configuration of the optical splitting amplifier section 4 is not limited to that shown in ~~Fig. 1~~ Figs. 1A and 1B. For example, a time division multiplexer may be used as an optical splitter.

Page 29, lines 20-27 and Page 30, lines 1-11, delete current paragraph and insert therefor:

Page 29, lines 20-27 and Page 30, lines 1-11:

Hereinbelow, the present embodiment will be described in further detail. Referring to Fig. 1A, for the single wavelength oscillatory laser 11 oscillating at a single wavelength, the present example uses, a laser, such as a distributed feedback (DFB) semiconductor laser. The DFB semiconductor laser is characterized by an InGaAsP construction, a 1.544 μm oscillation wavelength, and a 20 mW continuous output (which hereinbelow will be referred to as "CW output"). In addition, the DFB semiconductor laser is configured such that, instead of a Fabry-Pelot resonator, a diffraction grating is formed in a semiconductor laser, in which single longitudinal mode oscillation is performed under any condition. Thus, since the

DFB semiconductor laser performs the single longitudinal mode oscillation, the oscillation spectral linewidth can be controlled to be 0.01 pm or less. Alternatively, for the single wavelength oscillatory laser 11, the present example may be configured using a light source such as an erbium(Er)-doped fiber laser capable of generating a laser beam having a wavelength region similar to the above and a narrowed bandwidth.

Page 40, lines 26-27 and Page 41, lines 1-16, delete current paragraph and insert therefor:

Referring to Fig. 1A, the laser beams passed through the m-group delay fibers (optical fibers 17-1 to 17-n) are incident on the respective optical amplifier units 18-1 to 18-n, and are amplified thereby. The individual optical amplifier units 18-1 to 18-n of the present example have optical fiber amplifiers. However, as in the case of, particularly, the last-stage optical fiber amplifier, when high-intensity light propagates through the optical fibers, the wavelength width of the propagated light is expanded by influences of, for example, SPM (self phase modulation), SRS (stimulated raman scattering), and SBS (stimulated brillouin scattering), which are attributable to the optical-fiber nonlinear effects. Hereinbelow will be described an example configuration that mitigates the wavelength width expansion by reducing the influence of the nonlinear effects. While description given hereinbelow will cover several example configurations of an optical amplifier unit that may be used for the optical amplifier unit 18-1, the example configurations may similarly be used for the other optical amplifier units 18-2 to 18-n.

Page 42, lines 26-27 and Page 43, lines 1-11, delete current paragraph and insert therefor:

In the present example, the laser beam LB3 from the optical fiber 17-1 shown in Fig. 1A is led via the WDM device 21A to be incident on the amplifying optical fiber 22, and is amplified thereby. Then, the laser beam LB3 amplified by the amplifying optical fiber 22 is

incident on the amplifying optical fiber 25 via the WDM device 21B, the narrow band filter 24A, the isolator IS3, and WDM device 21C; and the incident laser beam LB3 is thereby amplified again. Via the WDM device 21D, the amplified laser beam LB3 propagates through one of optical fibers that constitute the fiber bundle 19 shown in Fig. 1A(the aforementioned optical fiber may be an extended portion of an output terminal of the amplifying optical fiber 25).

Page 43, lines 12-26, delete current paragraph and insert therefor:

The total of amplification gains according to the second-stage optical fiber amplifiers 22 and 25 is 46 dB (39,810 times) as one example. When the total number of channels (m·n pieces) output from the splitters 16-1 to 16-m shown in Fig. 1B is 128, and the average output power of each of the channels is about 50 μm, the average output power of all the channels is about 6.4 mW. When a laser beam of each of the channel is amplified at about 46 dB, the average output power of the laser beam output from each of the optical amplifier units 18-1 to 18-n is about 2 W. When the above is assumed to have been pulsed at a pulsewidth of 1 ns, and a pulse frequency of 100 kHz, the peak output power of each of the laser beams is 20 kW. Also, the average output power of the laser beam Lb4 output from the fiber bundle 19 is about 256 W.

Page 43, lines 27 and Page 44, lines 1-13, delete current paragraph and insert therefor:

In the present example, coupling losses in the splitters 14 and 16-1 to 16-m shown in Fig. 1A are not taken into consideration. However, even when the coupling losses occur, the output powers of the laser beams of the individual channels can be unformed to be the above-described value (for example, the peak output power of 20 kW). This can be achieved by increasing at least one of the amplification gains obtained according to the optical fiber amplifiers 22 and 25 by the amount of the loss. In addition, the value of the output power (output power of the fundamental wave) of the single wavelength oscillatory laser 11 shown

in Fig. 1A can be controlled larger or smaller than the aforementioned value. This can be achieved by controlling the amplification gains obtained according to the optical fiber amplifiers 22 and 25.

Page 44, lines 14-27 and Page 45, lines 1-4, delete current paragraph and insert therefor:

Referring to the example configuration shown in Fig. 2, the narrow band filter 24A removes ASE (amplified spontaneous emission) light occurring in each of the optical fiber amplifier 13 shown in Fig. 1A and the amplifying optical fiber 22 shown in Fig. 2, and lets the laser beam (having a wavelength width of 1 pm or less) output from the single wavelength oscillatory laser 11 shown in Fig. 1A to transmit. Thereby, the narrow band filter 24A substantially makes the wavelength width of the transmitted beam to be a narrow band. This enables the amplification gain of the laser beam to be prevented from being reduced by the incidence of the ASE light. In this case, the narrow band filter 24A preferably has a transmission wavelength width of about 1 pm. However, since the wavelength width of the ASE light is several tens of nm, the ASE light can be removed not to cause a problem in practice even by using a currently available narrow band filter with a transmission wavelength width of about 100 pm.

Page 45, lines 5-11, delete current paragraph and insert therefor:

Suppose the output wavelength of the single wavelength oscillatory laser 11 in Fig. 1A is positively changed. In this case, while the narrow band filter 24A may be replaced according to the output wavelength. However, preferably, a narrow band filter having a transmission wavelength width (equivalent to a variable range (about ±20 pm, as mentioned above as an example, for an exposure apparatus) is used.

Page 50, lines 25-27 and Page 51, lines 1-14, delete current paragraph and insert therefor:

Hereinbelow, another example of the present embodiment according to the present invention will be described with reference to Figs. 1A, 1B, 2, 7A, 7B, and 7C. According to the above-described embodiment, the pulsewidth of the laser beam output from the optical modulating device 12 shown in Fig. 1A is set to about 1 ns. With the pulsewidth which is thus short, when the peak output power is increased, an unexpected case can occur in which the frequency expansion is increased due to SPM (self phase modulation), particularly in the rear-stage optical fiber amplifier. As such, in the present example, the width of the output pulse in the optical modulating device 12 is set to a width that is several times a pulsewidth (about 1 ns in the present example) which is determined depending on the transfer limit in a required frequency width, for example, in a range of from 2 to 5 ns, and the pulse waveform is controlled to maximize the pulse transient time.

Page 51, lines 15-27 and Page 52, lines 1-3, delete current paragraph and insert therefor:

Figs. 7A, 7B and 7C show example pulse waveforms in individual portions. Intensity variations with respect a time t of the laser beam LB2 output from the optical modulating device 12 shown in Fig. 1A are represented as a waveform 28A shown by a solid line in Fig. 7B. Fig. 7B shows that a pulsewidth ΔtA of the waveform 28A is set to a level of two times a pulsewidth ΔtB of a waveform 28B, shown by a dotted line, which is determined depending on the transfer limit in a desired frequency width. In this case, the laser beam LB1 output from the single wavelength oscillatory laser 11 shown in Fig. 1A may be a CW wave as shown by the solid line in Fig. 7A. However, when the laser beam LB1 is controlled to be a pulsed beam having a width larger than the pulsewidth ΔtA, as a waveform 27 shown by a double-dotted chain line, use efficiency of the laser beam can be improved.

Page 52, lines 4-20, delete current paragraph and insert therefor:

In addition, suppose the optical amplifier unit 18 shown in Fig. 2 is assumed to be used for the optical amplifier unit 18-1 shown in Fig. 1A. In this case, when the pulsewidth of the laser beam LB2 is increased as described above, while the SPM influence is reduced particularly in the last-stage optical fiber amplifier 25, the SBS (stimulated brillouin scattering) influence is increased. Nevertheless, however, bleaching of the gain occurs in the last-stage optical fiber amplifier 25. Hence, as shown by a solid line of waveform 29A in Fig. 7C, the pulsewidth of the laser beam LB3 output from the optical amplifier unit 18 is reduced shorter than that of a waveform 29B that is shown by a dotted line and that corresponds as is to the laser beam LB2. Thereby, the adverse effect of the pulsewidth expanded in the optical modulating device 12 is reduced; and consequently, the wavelengths-in-width of ultraviolet lights to be finally output overall can be narrowed.

Page 52, between lines 21-27 and Page 53, lines 1-13, insert a new paragraph as follows:

In the above-described embodiment, the laser light source having an oscillation wavelength of about 1.544 μm is used for the single wavelength oscillatory laser 11. Instead of this laser light source, however, the embodiment may use a laser light source having an oscillation wavelength in a range of from 1.099 to 1.106 μm. For this laser light source, either a DFB semiconductor laser or an ytterbium(Yb)-doped fiber laser may be used. In this case, for the optical fiber amplifier in the rear-stage optical amplification section, the configuration may use an ytterbium(Yb)-doped fiber (YDFA) that performs amplification in a wavelength zone of 990 to 1200 nm including the wavelength of the amplifier section. In this case, ultraviolet light having a wavelength of 157 to 158 nm wave that is substantially the same wavelength of the F_2 laser can be obtained by outputting the seventh-order harmonic wave in the wavelength conversion section 20 shown in Fig. 1B. In practice, ultraviolet light

having substantially the same wavelength as that of the F_2 laser can be obtained by controlling the oscillation wavelength to be about 1.1 μm.

Page 57, lines 17-20, delete current paragraph and insert therefor:

Hereinbelow, a description will be made regarding example configurations of the wavelength conversion section 20 used in the ultraviolet light generator of the embodiment shown in Figs. 1A and 1B.

Page 57, lines 21-27 and Page 58, lines 1-20, delete current paragraph and insert therefor:

Fig. 8A shows the wavelength conversion section 20 that is capable of obtaining the eighth-order harmonic wave through repetition of the second-order harmonic wave generation. In Fig. 8A, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm (the frequency is represented by "ω") output from an output terminal 19a of an optical fiber bundle 19 is incident on a first-stage nonlinear optical crystal 502. The second-order harmonic wave generation is performed therein to generate the second-order harmonic wave having a twofold frequency 2ω (wavelength: 1/2 of 772 nm) of the frequency ω. The generated second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 503 through a lens 505. Similar to the above, through the second-order harmonic wave generation, there is generated fourth-order harmonic wave having a twofold frequency of the frequency 2ω of the incident wave, that is, a fourfold frequency 4ω (wavelength: 1/4 of 386 nm) with respect to the fundamental wave. The generated fourth-order harmonic wave is then transferred to a third-stage nonlinear optical crystal 504 through a lens 506. Similarly, through the second-order harmonic wave generation, there is generated eighth-order harmonic wave having a twofold frequency of the frequency 4ω of the incident wave, that is, an eightfold frequency 8ω (wavelength: 1/8 of 193 nm) with respect to the fundamental wave. The eighth-order harmonic wave is output as laser beam LB5. Thus, the example

configuration performs wavelength modulations in the following order: fundamental wave (wavelength: 1.544 μm) → second-order harmonic wave (wavelength: 772 nm) → fourth-order harmonic wave (wavelength: 386 nm) → eighth-order harmonic wave (wavelength: 193 nm).

Page 59, lines 20-27 and Page 60, lines 1-5, delete current paragraph and insert therefor:

Referring to Fig. 8A, a converging lens, which is effective for improving the incidence efficiency of laser beam LB4, is preferably provided between the fiber bundle 19 and the nonlinear optical crystal 502. In this case, each of the optical fibers constituting the fiber bundle 19 has a mode diameter (core diameter) of about 20 μm, and a region where the conversion efficiency in the nonlinear optical crystal has a size of about 200 μm. As such, a lens with a very low magnification of about 10× magnification may be provided in units of the optical fiber to converge the laser beam output from each of the optical fibers into the nonlinear optical crystal 502. This applies also to other example configurations described below.

Page 60, lines 6-25, delete current paragraph and insert therefor:

Fig. 8B shows a wavelength conversion section 20A that is capable of obtaining the eighth-order harmonic wave by combining the second-order harmonic wave generation and sum frequency generation. Referring to Fig. 8B, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm output from the output terminal 19a of the fiber bundle 19 is incident on a first-stage nonlinear optical crystal 507 formed of the LBO crystal and controlled by the NCPM method. In the crystal 507, there is generated the second-order harmonic wave (wavelength: 722 nm) according to the second-order harmonic wave generation. In addition, a part of the fundamental wave is transmitted as is through the nonlinear optical crystal 507. Both the fundamental wave and second-order harmonic wave

in a linearly polarized state are transmitted trough a wavelength plate 508 (for example, a 1/2 wavelength plate), and only the fundamental wave is output in a 90-degree rotated direction of polarization. The fundamental wave and the second-order harmonic wave individually pass through a lens 509 and are incident on a second-stage nonlinear optical crystal 510.

Page 63, lines 8-27, delete current paragraph and insert therefor:

Page 63, lines 8-27:

The configuration between the second-stage nonlinear optical crystal 510 and the fourth-stage nonlinear optical crystal 517 is not limited to that shown in Fig. 8B. This configuration may be arbitrarily arranged as long as it has the same optical path lengths for the sixth-order harmonic wave and the second-order harmonic wave to cause the sixth-order harmonic wave and the second-order harmonic wave to be incident on the fourth-stage nonlinear optical crystal 517. Moreover, for example, the third-stage and fourth-stage nonlinear optical crystals 514 and 517 may be disposed on the same optical axis of the second-stage nonlinear optical crystal 510. In this configuration, the third-stage nonlinear optical crystal 514 is used to convert only the third-order harmonic wave into the sixth-order harmonic wave according to the second-order harmonic wave generation, and the converted harmonic wave and the non-converted second-order harmonic wave together may be incident on the fourth-stage nonlinear optical crystal 517. This configuration avoids the necessity of using the dichroic mirrors 511 and 516.

Page 64, lines 1-19, delete current paragraph and insert therefor:

For the individual wavelength conversion sections 20 and 20A shown in Figs. 8A and 8B, the average output power of the per-channel eighth-order harmonic waves (wavelength: 193 nm) were experimentally obtained. As described in the above-described embodiment, the output of the fundamental wave at each of the channel output terminal is characterized by a peak power of 20 kW, a pulsewidth of 1 ns, a pulse repetition frequency of 100 kHz, and an

average output power of 2W. As a result, the per-channel average output powers of the eighth-order harmonic waves were 229 mW in the wavelength conversion section 20 shown in Fig. 8A, and 38.3 mW in the wavelength conversion section 20A shown in Fig. 8B. Accordingly, the average output powers from the bundle of all the 128 channels are 29 W in the wavelength conversion section 20, and 4.9 W in the wavelength conversion section 20A. As such, in either of the wavelength conversion sections 20 and 20A, ultraviolet light having a wavelength of 193 nm beam, which is sufficient as an exposure-apparatus-dedicated light source can be provided.

Page 65, lines 18-27, delete current paragraph and insert therefor:

Hereinbelow, a description will be made regarding an example configuration of a wavelength modulator section that enables ultraviolet light having substantially the same wavelength as that of the F_2 laser (wavelength: 157 nm). To implement the above, as the wavelength conversion section 20, the configuration may be arranged to use a wavelength conversion section capable of generating the tenth-order harmonic wave with 1.57 μm wavelength of the fundamental wave generated in the single wavelength oscillatory laser 11 shown in Fig. 1A.

Page 66, lines 1-16, delete current paragraph and insert therefor:

Fig. 9A shows a wavelength conversion section 20B that enables the tenth-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. 9B, the fundamental wave of the laser beam LB4, having a wavelength of 1.57 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 602 formed of the LBO crystal, and is converted into the second-order harmonic wave according to the second-order harmonic wave generation. The second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 604 formed of LBO via a lens 603, and is

converted into the fourth-order harmonic wave according to the second-order harmonic wave generation; and a part of the second-order harmonic wave is transmitted therethrough without being converted.

Page 68, lines 18-27 and Page 69, lines 1-8, delete current paragraph and insert therefor:

Fig. 9B shows a wavelength conversion section 20C that enables the seventh-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. 9B, the laser beam LB4 (fundamental wave), having a wavelength of 1.099 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 702 formed of the LBO crystal, and the second-order harmonic wave is generated therein according to the second-order harmonic wave generation. A part of the fundamental wave is transmitted as is therethrough. Both the fundamental wave and second-order harmonic wave transmits in a linearly polarized state transmits through a wavelength plate 703 (such as a 1/2 wavelength plate), and only the direction of polarization of only the fundamental wave is rotated through 90 degrees. The fundamental wave and the second-order harmonic wave is led through a lens 704 to be incident on a second nonlinear optical crystal 705 formed of the LBO crystal. The third-order harmonic wave is generated therein according to the sum frequency generation, and a part of the second-order harmonic wave is transmitted as is therethrough.

Page 70, lines 23-27 and Page 71, lines 1-14, delete current paragraph and insert therefor:

As is apparent from Fig. 1A, in the above-described embodiment, the combined light of the outputs of the n optical amplifier units 18-1 to 18-n in the m-group is converted in wavelength by using the single wavelength conversion section 20. Alternatively, however,

the configuration may be arranged such that, for example, m' units (m' = "2" or larger inger) wavelength conversion sections are provided. In the alternative configuration, the outputs of the m-group optical amplifier units 18-1 to 18-n are divided in units of n' outputs into m' groups, the wavelength conversion is performed for one of the wavelength conversion section in units of one of the groups, and the obtained m' ultraviolet light beams (in the present example, m' = "4", "5", or the like) are combined. Thus, the wavelength conversion section 20 is not limited to that having the above-described configuration. Moreover, for example, a CBO crystal (CsB_3O_5), a lithium tetraborate $Li_2B_4O_7$ (LBO), a KAB ($K_2Al_2B_4O_7$), or a GdYCOB ($Gd_XY_{1-x}Ca_4O(BO_3)_3$), may be used as an alternative crystal for the nonlinear optical crystal.

Page 71, lines 15-27 and Page 72, lines 1-3, delete current paragraph and insert therefor:

According to the ultraviolet light generator of the above-described embodiment, the diameter of the output terminal of the fiber bundle 19, shown in Fig. 1A, even with all the channels being included, is about 2 mm or smaller. As such, one or several units of the wavelength conversion sections 20 are sufficient to perform the wavelength conversion of all the channels. In addition, since flexible optical fibers are used for the output terminals, the flexibility in configuration is very high. For example, the configuration sections such as the wavelength conversion section, the single wavelength oscillatory laser, and the splitter, can be separately disposed. Consequently, the ultraviolet light generator of the present example enables the provision of an ultraviolet laser device that is inexpensive and compact, and has a low spatial coherence while it is of a single wavelength type.

Page 72, lines 4-26, delete current paragraph and insert therefor:

Hereinbelow, an example exposure apparatus using the ultraviolet light generator shown in Fig. 1A will be described. Fig. 10 shows the exposure apparatus of the present

example. Referring to Fig. 10, devices usable for an exposure light source 161 include, for example, a device with an ultraviolet region of 193 nm, 157 nm, or the like based on the wavelength of a laser beam that is output from the ultraviolet light generator shown in Fig. 1A. A laser beam LB5 that has been output from the exposure light source 161 is incident as exposure light IL on an illumination system 162. The illumination system 162 is configured of, for example, an optical integrator (homogenizer) for homogenizing illuminance distributions of the exposure light IL, an aperture diaphragm, a field diaphragm (reticle blind), and a condenser lens. In the aforementioned configuration, the exposure light IL output from the illumination system 162 illuminates a slit-like illumination region of a pattern surface of a reticle 163 set as a mask to provide a homogeneous illuminance distribution. In the present example, since the spatial coherence of the exposure light IL is so low that the configuration of a member for reducing the spatial coherence in the illumination system 162 can be simplified, and the exposure apparatus can therefore be further miniaturized.

Page 74, lines 22-27 and Page 75, lines 1-19, delete current paragraph and insert therefor:

Exposure-light-amount control in the above-described scan-exposure operation may be implemented in the following manner. Control is performed for at least one of the pulse repetition frequency f, which is defined by the optical modulating device 12 shown in Fig. 1A, and the interchannel delay time, which is defined by the delaying devices (optical fibers 15-1 to 15-m, and 17-1 to 17-n). The control is thus performed to cause a fundamental-wave generator section 171 to oscillate a plurality of pulsed beams at equal time intervals during scan-exposure operation. In addition, according to the sensitivity property of the photoresist, at least one of the optical intensity of the pulsed beam on the wafer 166, the scan speed for the wafer 166, the pulsed-beam oscillation interval (frequency), and the width of the pulsed beam in the scan direction for the wafer 166 (that is, an radiation region thereof) to thereby

control the integrated luminous quantity of a plurality of pulsed beams irradiated in a period in which the individual points of the wafer traverse the radiation region. At this time, in consideration of the throughput, least one of other control parameters representing the pulsed-beam optical intensity, the oscillation frequency, and the radiation region width is preferably controlled so that the scan speed for the wafer 166 is substantially maintained to be the maximum speed of the wafer stage 167.

Page 75, lines 20-27 and Page 76, lines 1-8, delete current paragraph and insert therefor:

Fig. 11 shows another exposure apparatus using the ultraviolet light generator of the present example. Referring to Fig. 11, the ultraviolet light generator shown in Fig. 1A is attached apart. Specifically, referring to Fig. 11 showing the portions corresponding to those shown in Fig. 10 by assigning the same reference symbols, a wavelength conversion section 172 corresponding to the wavelength conversion section 20 shown in Fig. ~~1(a)~~ 1A is mounted on the exposure apparatus mainbody. On the other hand, a light-source mainbody section 171 corresponding to the members of from the single wavelength oscillatory laser 11 to optical splitting amplifier section 4 shown in Fig. 1A are provided outside of the exposure apparatus mainbody, and a coupling-dedicated optical fiber 173 is used to couple therebetween. The coupling-dedicated optical fiber 173 corresponds to the fiber bundle 19 shown in Fig. 1A.

Page 78, lines 8-18, delete current paragraph and insert therefor:

In the present example, a laser beam from the light-source mainbody section 171 is fed to a wavelength conversion section 179 via an optical fiber 178. For the wavelength conversion section 179, the present example uses a wavelength conversion section that is similar to the wavelength conversion section 20 shown in Fig. 1A and that is relatively small. The wavelength conversion section 179 is integrally provided on the frame that holds the

alignment system 180, in which ultraviolet light that has been output from the wavelength conversion section 179 is used as illumination light.

Page 79, lines 9-25, delete current paragraph and insert therefor:

The exposure apparatus of the above-described embodiment shown, for example, in Fig. 11, may include a spatial-image measuring system. The spatial-image measuring system may be such that the mark provided on the reticle 163 and the reference mark provided on the reticle stage 164 are illuminated with illumination light having the same wavelength, and a mark image formed by the projection optical system 165 is detected through an opening (such as a slit) provided on the wafer stage 167. For a light source generating the illumination light for the spatial-image measuring system, a light source (similar to the ultraviolet light generator shown in Figs. 1A and 1B) having the same configuration as that of the above-described light source (171 and 179) may be separately provided. Alternatively, the exposure-dedicated light source formed of the members including the light-source mainbody section 171 and the illumination system 162 may be shared.

Page 79, lines 26-27 and Page 80, lines 1-10, delete current paragraph and insert therefor:

In the above-described embodiment, description has been made that the laser device shown in Figs. 1A and 1B is used either as the exposure-dedicated light source or as the light source of the alignment system or the spatial-image measuring system. However, the laser device may be used as a regulating light source of a detecting system or an optical system for marks other than the above. In addition, the laser device may be used not only as the light source of the exposure apparatus, the testing apparatus, or the like used in the device-manufacturing step, but also as a light source of various other apparatuses, regardless of the use and like thereof (an example is an apparatus using an excimer laser as a light source, such as a laser medical treatment apparatus for performing medical treatment for, for example, the

near site and the astigmatism, by correcting, for example, the curvature or the irregularity of the cornea).

IN THE CLAIMS:

Please replace claims 1-28 as follows:

1. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, and a narrow band filter and an isolator disposed between the plural stages of the optical fiber amplifiers; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

2. (Amended) An exposure apparatus as recited in claim 1, wherein

the laser device includes an excitation-light generating light source which generating excitation light which is to be used at at least one of the plural stages of the optical fiber amplifiers, and the optical amplifier is formed such that a reflection film which reflects the excitation light is formed at one end of the optical fiber coupled to the narrow band filter.

3. (Amended) An exposure apparatus as recited in claim 1, wherein

the narrow band filter and the isolator reduce noise of a wavelength corresponding to a phonon sideband.

4. (Amended) An exposure apparatus as recited in claim 1, wherein

at least three stages of the optical fiber amplifiers are provided, and the narrow band filter and the isolator are respectively provided between the individual optical fiber amplifiers.

5. (Amended) An exposure apparatus as recited in claim 1, wherein

a gate device, which performs timewise removal of ASE (amplified spontaneous emission), is further provided between the plural stages of the optical fiber amplifiers.

6. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of amplifying optical fibers which serially amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates excitation light for at least one stage of the amplifying optical fiber of the plural stages of the amplifying optical fibers, a narrow band filter or an isolator disposed between the plural stages of the amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

7. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, a plurality of excitation-light generating light sources which individually generate excitation lights for each of the plural stages of the optical fiber amplifiers, and a narrow band filter disposed between the plural stages of the optical fiber amplifiers, wherein a reflection film which reflects the excitation light is formed at one end of each of the optical fibers coupled to both sides of the narrow band filter; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

8. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical modulation section which modulates the laser light generated by the laser light generation section with a predetermined repetition frequency into pulsed light having a predetermined width;

an optical amplification section including an optical fiber amplifier which amplifies the laser light which has passed through the optical modulation section; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal, wherein

the width of the pulsed light modulated by the optical modulation section is set wider than a pulsewidth set for obtaining a predetermined wavelength width with finally generated ultraviolet light.

9. (Amended) An exposure apparatus as recited in claim 8, wherein the width of the pulsed light modulated by the optical modulation section is 2 to 5 ns.

10. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including an optical fiber amplifier which amplifies the laser light generated by the laser light generation section, a transmitting optical fiber

which propagates the laser light amplified by the optical fiber amplifier, and a narrow band filter disposed between the optical fiber amplifier and the transmitting optical fiber; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

11. (Amended) An exposure apparatus as recited in claim 10, wherein the narrow band filter is concurrently used as a wavelength division multiplexing device for multiplexing which feeds excitation light to the optical fiber amplifier.

12. (Amended) An exposure apparatus as recited in claim 1, wherein
the laser device includes an optical modulation section which modulates the laser light generated by the laser light generation section into pulsed light and which sets the width of the pulsed light to be wider than a pulsewidth set for obtaining a predetermined wavelength width with the ultraviolet light.

13. (Amended) An exposure apparatus as recited in claim 12, wherein
the laser device includes an optical splitter which splits the laser light generated by the laser light generation section into a plurality of laser light beams, the optical amplification section is independently provided for each of the plural split laser light beams, and
the laser device further includes a regulator which regulates an amplification gain of the optical amplification sections so that outputs of the plurality of split laser light beams are substantially uniformalized.

14. (Amended) An exposure apparatus as recited in claim 1, ~~characterized in that~~ wherein the optical fiber amplification section is an erbium-doped fiber amplifier and uses laser light having a wavelength of (980±10) nm as the excitation light for the amplifier.

15. (Amended) An exposure apparatus as recited in claim 1, wherein a multilayer film filter or a fiber Bragg grating is used for the narrow band filter.

16. (Amended) An exposure apparatus as recited in claim 1, wherein the laser light generation section includes a single wavelength oscillatory laser which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, and an oscillation-wavelength control means which controls an oscillation wavelength of the generated laser light to be a predetermined wavelength.

17. (Amended) An exposure apparatus as recited in claim 1, wherein
the laser device further includes an optical splitter which splits the laser light generated by the laser light generation section into a plurality of laser light beams,
the optical amplification section is independently provided for each of the plural split laser light beams, and
the wavelength conversion section performs collective wavelength conversion of a bundle of the laser light beams output from the plural optical amplification sections.

18. (Amended) An exposure apparatus as recited in claim 17, further comprising a regulator which regulates an amplification gain of the optical amplification sections so that outputs of the plurality of split laser light beams are substantially uniformalized.

19. (Amended) An exposure apparatus as recited in claim 17, wherein the regulator changes the output of the excitation light used for the optical fiber amplifier in the optical amplification section.

20. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein

the laser device includes:

a laser generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, an optical splitter which splits the laser light into a plurality of laser light beams, a plurality of optical fiber amplifiers which respectively and independently amplify the plurality of split laser light beams, a wavelength conversion section which performs wavelength conversion of the amplified laser light beams, and

the laser device includes a regulator which regulates an amplification gain at at least one of the plurality of the optical fiber amplifiers so that outputs of the plurality of split laser light beams are substantially uniformalized.

21. (Amended) An exposure apparatus as recited in claim 20, wherein the regulator controls an excitation-light generating light source which generates excitation light used in the at least one optical fiber amplifier.

22. (Amended) An exposure apparatus as recited in ~~of~~ claim 1 wherein

the laser light generation section generates single wavelength laser light having a wavelength of near 1.5 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.5 μm into ultraviolet light of an eighth-order harmonic wave or a tenth-order harmonic wave and outputs the converted light.

23. (Amended) An exposure apparatus as recited in claim 1 wherein

the laser light generation section generates a single wavelength laser light having a wavelength of near 1.1 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.1 μm into ultraviolet light of a seventh-order harmonic wave thereof and outputs the converted light.

24. (Amended) An exposure apparatus as recited in claim 1 comprising:

an illumination system which radiates ultraviolet light from the laser device onto a mask as the first object: and

a projection optical system which projects an image of a pattern of the mask onto a substrate as the second object.

25. (Amended) An exposure method using an exposure apparatus as recited in claim 1, comprising using the ultraviolet light output from the laser device to perform alignment between the first object and the second object.

26. (Amended) A method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and that expose a second object with the ultraviolet light which has passed through the pattern of the first object, comprising configuring the laser device by disposing, with a predetermined relationship,

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region,

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, and a narrow band filter and an isolator disposed between the plural stages of the optical fiber amplifiers, and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

27. (Amended) A method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which exposes a second object with the ultraviolet light which has passed through the pattern of the first object, comprising configuring the laser device by disposing, with a predetermined relationship,
a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;
an optical amplification section including plural stages of amplifying optical fibers which serially amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates excitation light for at least one stage of the amplifying optical fiber of the plural stages of the amplifying optical fibers, a narrow band filter or an isolator disposed between the plural stages of the amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

28. (Amended) A device manufacturing method including transferring a mask pattern onto a substrate by using the exposure apparatus as recited in claims 1.

REMARKS

Claims 1-28 are pending. By this Preliminary Amendment, the specification is amended and claims 1-28 are amended. Prompt and favorable examination to the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. §1.121(b)(1)(iii)) and claim (37 C.F.R. §1.121(c)(1)(ii)).

Respectfully submitted,

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MAC:TJP/cmm

Attachment:
Appendix

Date: September 4, 2002

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DEPOSIT ACCOUNT USE AUTHORIZATION
Please grant any extension necessary for entry;
Charge any fee due to our Deposit Account No. 15-0461

APPENDIX

Changes to Specification:

Page 1, before line 1, a new paragraph is added.

Page 7, lines 21-27 and Page 8, lines 1-9:

A first exposure apparatus of the present invention illuminates a pattern of a first object ~~(163)~~ with ultraviolet light from a laser device and exposes a second object ~~(166)~~ with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section ~~(18)~~ including plural stages of optical fiber amplifiers ~~(22, 25)~~ which serially amplifies the laser light generated by the laser light generation section, and a narrow band filter ~~(24A)~~ and an isolator ~~(IS3)~~ between the plural stages of the optical fiber amplifiers; and a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 8, lines 16-27 and Page 9, lines 1-8:

A second exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light output from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a

wavelength range of from an infrared region to a visible region; an optical amplification section ~~(18A; 18B)~~ including plural stages of amplifying optical fibers ~~(22 and 25)~~ which amplify the laser light generated by the laser light generation section, an excitation-light generating light source ~~(23A)~~ which generates a plurality of amplifying excitation light beams, a narrow band filter ~~(24A)~~ or an isolator ~~(IS3)~~ disposed between the plurality of the amplifying optical fibers, and a bypass member ~~(21B, 21C, and 30)~~ which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 9, lines 9-27 and Page 10, line 1:

A third exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section ~~(18C)~~ including plural stages of optical fiber amplifiers ~~(22 and 25)~~ which amplify the laser light generated by the laser light generation section, a plurality of excitation-light generating light sources ~~(23A and 23D)~~ which individually generate excitation light for each of the plural stages of the amplifying optical fibers, and a narrow band filter ~~(24A)~~, a reflection film which reflects the excitation light being formed at one of each of the optical fibers coupled to both sides of the narrow band filter; and a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 10, lines 2-22:

A fourth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical modulation section ~~(12)~~ which modulates the laser light generated by the laser light generation section with a predetermined repetition frequency into pulsed light having a predetermined width; an optical amplification section ~~(18-1)~~ including an optical fiber amplifier ~~(22 and 25)~~ which amplifies the laser light which has passed through the optical modulation section; and a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal, the width of the pulsed light modulated by the optical modulation section is set wider than a pulsewidth set for obtaining a predetermined wavelength width with finally generated ultraviolet light.

Page 10-, lines 23-27 and Page 11, lines 1-13:

A fifth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section ~~(18D)~~ including an optical fiber amplifier ~~(25)~~ which amplifies the laser light generated by the laser light generation section, a transmitting optical fiber ~~(26)~~ which propagates the laser light amplified by the optical fiber amplifier, and a narrow band filter

~~(24A)~~ disposed between the optical fiber amplifier and the transmitting optical fiber; and a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 11, lines 14-27 and Page 12, lines 1-3:

A sixth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, an optical splitter which splits the laser light into a plurality of laser light beams, a plurality of optical fiber amplifiers which respectively and independently amplify the plurality of split laser light beams, a wavelength conversion section ~~(20)~~ which performs wavelength conversion of the amplified laser light beams, and the laser device includes a regulator which regulates an amplification gain at at least one of the plurality of the optical fiber amplifiers so that outputs of the plurality of amplified laser light beams are substantially uniformalized.

Page 17, lines 14-27 and Page 18, lines 1-3:

Preferably, each of the above-described laser devices is configured to further include an optical splitter ~~(14, and 16-1 to 16-m)~~ which splits the laser light generated by the laser light generation section into a plurality of laser light beams, and, in this configuration, optical amplification sections ~~(18-1 to 18-n)~~ are independently provided for the plurality of split laser beams respectively, and the wavelength conversion section collects fluxes of laser beams output from the plurality of optical amplification sections and performs wavelength

conversion thereof. Thus, the laser light split by the optical splitters are sequentially imparted with predetermined differences in optical path lengths and therefore, the spatial coherence of the laser light finally bundled can be reduced. Moreover, since each of the laser light beams is generated by the common laser light generation section, the spectral linewidth of the finally obtained ultraviolet light is narrow.

Page 19, lines 19-27 and Page 20, line 1:

The exposure apparatus of the present invention further includes an illumination system ~~(162)~~ which irradiates a mask~~(163)~~ with ultraviolet light from the laser device, and a projection optical system ~~(165)~~ which projects an image of a pattern of the mask onto a substrate ~~(166)~~, wherein the substrate is exposed with the ultraviolet light passed through the pattern of the mask. With the laser device of the present invention being used, the exposure apparatus can be miniaturized overall, and the maintainability thereof is increased.

Page 20, lines 9-27:

Hereinbelow, a first exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object ~~(163)~~ with ultraviolet light from a laser device and which expose a second object ~~(166)~~ with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, plural stages of optical fiber amplifiers ~~(22 and 25)~~ which serially amplify the laser light generated by the laser light generation section, an optical amplification section ~~(18)~~ including a narrow band filter ~~(24A)~~ and an isolator ~~(IS3)~~ between the plural stages of optical fiber amplifiers, and a wavelength

conversion section ~~(20)~~ which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 21, lines 1-23:

A second exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section ~~(11)~~ which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section ~~(18A; 18B)~~ including plurality of amplifying optical fibers ~~(22 and 25)~~ which amplify the laser light generated by the laser light generation section, an excitation-light generating light source ~~(23A)~~ which generates a plurality of amplifying excitation light beams, a narrow band filter ~~(24A)~~ or an isolator ~~(IS3)~~ disposed between the plurality of amplifying optical fibers, and a bypass member ~~(21B, 21C, and 30)~~ which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section ~~(20)~~ for performing wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Page 22, lines 2-4:

~~Fig. 1 is a~~ <u>Figs. 1A and 1B are</u> diagram<u>s</u> showing an example of an ultraviolet light generator according to an embodiment of the present invention.

Page 22, lines 5-7:

Fig. 2 is a diagram showing a first configuration example of optical amplifier units 18-1 to 18-n shown in ~~Fig. 1~~ Figs. 1A and 1B.

Page 22, lines 16-19:

~~Fig. 7 is a~~ Figs. 7A, 7B and 7C are diagrams showing waveforms of laser beams in individual portions of another example according to the present embodiment of the present invention.

Page 22, lines 20-24:

~~In Fig. 8, Fig. 8(a)~~ Fig. 8A is a diagram showing a first configuration example of a wavelength conversion section 20 shown in ~~Fig. 1~~ Figs. 1A and 1B, and ~~Fig. 8(b)~~ Fig. 8B is a diagram showing a second configuration example of the wavelength conversion section 20.

Page 22, line 25 and Page 23, lines 1-4:

~~In Fig. 9, Fig. 9(a)~~ Fig. 9A is a diagram showing a third configuration example of a wavelength conversion section 20, and ~~Fig. 9(b)~~ Fig. 9B is a diagram showing a fourth configuration example of the wavelength conversion section 20.

Page 23, lines 21-27 and Page 24, lines 1-3:

Fig. ~~1(a)~~ 1A shows an ultraviolet light generator according to the present example. Referring to Fig. ~~1(a)~~ 1A, a single wavelength oscillatory laser 11, which is provided as a laser light generation section, generates a laser beam LB1 that is formed of a continuous wave (CW) having a narrow spectral width and that has a wavelength of 1.544 μm. The laser beam LB1 is incident on an optical modulating device 12, which is provided as an optical modulator, via an isolator IS1 provided for blocking reverse light. The laser beam LB1 is

converted therein into a laser beam LB2 (pulsed beam), and the laser beam LB2 is then incident on an optical splitting amplifier section 4.

Page 27, lines 8-24:

Moreover, as shown in Fig. ~~1(b)~~ 1B, output terminals 19a of the fiber bundle 19 are bundled such that the m·n optical fibers (128 optical fibers in the present example) tightly contacts one another, and the outer shape thereof is circular in a cross-sectional view. In a practical configuration, however, the outer shape of the output terminals 19a and the number of optical fibers are determined according to, for example, the rear-stage configuration of the wavelength conversion section 20 and use conditions of the ultraviolet light generator of the present example. The clad diameter of each of the optical fibers constituting the fiber bundle 19 is about 125 μm. Accordingly, when 128 optical fibers are bundled circular, a diameter d1 of each of the output terminals 19a can be set to about 2 mm or smaller. The configuration of the optical splitting amplifier section 4 is not limited to that shown in ~~Fig. 1~~ Figs. 1A and 1B. For example, a time division multiplexer may be used as an optical splitter.

Page 29, lines 20-27 and Page 30, lines 1-11:

Hereinbelow, the present embodiment will be described in further detail. Referring to Fig. ~~1 (a)~~ 1A, for the single wavelength oscillatory laser 11 oscillating at a single wavelength, the present example uses, a laser, such as a distributed feedback (DFB) semiconductor laser. The DFB semiconductor laser is characterized by an InGaAsP construction, a 1.544 μm oscillation wavelength, and a 20 mW continuous output (which hereinbelow will be referred to as "CW output"). In addition, the DFB semiconductor laser is configured such that, instead of a Fabry-Pelot resonator, a diffraction grating is formed in a semiconductor laser, in which single longitudinal mode oscillation is performed under any condition. Thus, since the

DFB semiconductor laser performs the single longitudinal mode oscillation, the oscillation spectral linewidth can be controlled to be 0.01 pm or less. Alternatively, for the single wavelength oscillatory laser 11, the present example may be configured using a light source such as an erbium(Er)-doped fiber laser capable of generating a laser beam having a wavelength region similar to the above and a narrowed bandwidth.

Page 40, lines 26-27 and Page 41, lines 1-16:

Referring to Fig. ~~1(a)~~ 1A, the laser beams passed through the m-group delay fibers (optical fibers 17-1 to 17-n) are incident on the respective optical amplifier units 18-1 to 18-n, and are amplified thereby. The individual optical amplifier units 18-1 to 18-n of the present example have optical fiber amplifiers. However, as in the case of, particularly, the last-stage optical fiber amplifier, when high-intensity light propagates through the optical fibers, the wavelength width of the propagated light is expanded by influences of, for example, SPM (self phase modulation), SRS (stimulated raman scattering), and SBS (stimulated brillouin scattering), which are attributable to the optical-fiber nonlinear effects. Hereinbelow will be described an example configuration that mitigates the wavelength width expansion by reducing the influence of the nonlinear effects. While description given hereinbelow will cover several example configurations of an optical amplifier unit that may be used for the optical amplifier unit 18-1, the example configurations may similarly be used for the other optical amplifier units 18-2 to 18-n.

Page 42, lines 26-27 and Page 43, lines 1-11:

In the present example, the laser beam LB3 from the optical fiber 17-1 shown in Fig. ~~1(a)~~ 1A is led via the WDM device 21A to be incident on the amplifying optical fiber 22, and is amplified thereby. Then, the laser beam LB3 amplified by the amplifying optical fiber 22

is incident on the amplifying optical fiber 25 via the WDM device 21B, the narrow band filter 24A, the isolator IS3, and WDM device 21C; and the incident laser beam LB3 is thereby amplified again. Via the WDM device 21D, the amplified laser beam LB3 propagates through one of optical fibers that constitute the fiber bundle 19 shown in Fig. ~~1(a)~~ 1A(the aforementioned optical fiber may be an extended portion of an output terminal of the amplifying optical fiber 25).

Page 43, lines 12-26:

The total of amplification gains according to the second-stage optical fiber amplifiers 22 and 25 is 46 dB (39,810 times) as one example. When the total number of channels (m·n pieces) output from the splitters 16-1 to 16-m shown in Fig. ~~1(b)~~ 1B is 128, and the average output power of each of the channels is about 50 μm, the average output power of all the channels is about 6.4 mW. When a laser beam of each of the channel is amplified at about 46 dB, the average output power of the laser beam output from each of the optical amplifier units 18-1 to 18-n is about 2 W. When the above is assumed to have been pulsed at a pulsewidth of 1 ns, and a pulse frequency of 100 kHz, the peak output power of each of the laser beams is 20 kW. Also, the average output power of the laser beam Lb4 output from the fiber bundle 19 is about 256 W.

Page 43, line 27 and Page 44, lines 1-13:

In the present example, coupling losses in the splitters 14 and 16-1 to 16-m shown in Fig. ~~1(a)~~ 1A are not taken into consideration. However, even when the coupling losses occur, the output powers of the laser beams of the individual channels can be unformed to be the above-described value (for example, the peak output power of 20 kW). This can be achieved by increasing at least one of the amplification gains obtained according to the optical fiber

amplifiers 22 and 25 by the amount of the loss. In addition, the value of the output power (output power of the fundamental wave) of the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A can be controlled larger or smaller than the aforementioned value. This can be achieved by controlling the amplification gains obtained according to the optical fiber amplifiers 22 and 25.

Page 44, lines 14-27 and Page 45, lines 1-4:

Referring to the example configuration shown in Fig. 2, the narrow band filter 24A removes ASE (amplified spontaneous emission) light occurring in each of the optical fiber amplifier 13 shown in Fig. ~~1(a)~~ 1A and the amplifying optical fiber 22 shown in Fig. 2, and lets the laser beam (having a wavelength width of 1 pm or less) output from the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A to transmit. Thereby, the narrow band filter 24A substantially makes the wavelength width of the transmitted beam to be a narrow band. This enables the amplification gain of the laser beam to be prevented from being reduced by the incidence of the ASE light. In this case, the narrow band filter 24A preferably has a transmission wavelength width of about 1 pm. However, since the wavelength width of the ASE light is several tens of nm, the ASE light can be removed not to cause a problem in practice even by using a currently available narrow band filter with a transmission wavelength width of about 100 pm.

Page 45, lines 5-11:

Suppose the output wavelength of the single wavelength oscillatory laser 11 in Fig. ~~1(a)~~ 1A is positively changed. In this case, while the narrow band filter 24A may be replaced according to the output wavelength. However, preferably, a narrow band filter having a

transmission wavelength width (equivalent to a variable range (about ±20 pm, as mentioned above as an example, for an exposure apparatus) is used.

Page 50, lines 25-27 and Page 51, lines 1-14:

Hereinbelow, another example of the present embodiment according to the present invention will be described with reference to Figs. ~~1~~ 1A, 1B, 2, ~~and 7~~ 7A, 7B, and 7C. According to the above-described embodiment, the pulsewidth of the laser beam output from the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A is set to about 1 ns. With the pulsewidth which is thus short, when the peak output power is increased, an unexpected case can occur in which the frequency expansion is increased due to SPM (self phase modulation), particularly in the rear-stage optical fiber amplifier. As such, in the present example, the width of the output pulse in the optical modulating device 12 is set to a width that is several times a pulsewidth (about 1 ns in the present example) which is determined depending on the transfer limit in a required frequency width, for example, in a range of from 2 to 5 ns, and the pulse waveform is controlled to maximize the pulse transient time.

Page 51, lines 15-27 and Page 52, lines 1-3:

~~Fig. 7 shows~~ Figs. 7A, 7B and 7C show example pulse waveforms in individual portions. Intensity variations with respect a time t of the laser beam LB2 output from the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A are represented as a waveform 28A shown by a solid line in Fig. ~~7(b)~~ 7B. Fig. ~~7(b)~~ 7B shows that a pulsewidth ΔtA of the waveform 28A is set to a level of two times a pulsewidth ΔtB of a waveform 28B, shown by a dotted line, which is determined depending on the transfer limit in a desired frequency width. In this case, the laser beam LB1 output from the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A may be a CW wave as shown by the solid line in Fig. ~~7(a)~~ 7A.

However, when the laser beam LB1 is controlled to be a pulsed beam having a width larger than the pulsewidth ΔtA, as a waveform 27 shown by a double-dotted chain line, use efficiency of the laser beam can be improved.

Page 52, lines 4-20:

In addition, suppose the optical amplifier unit 18 shown in Fig. 2 is assumed to be used for the optical amplifier unit 18-1 shown in Fig. ~~1(a)~~ 1A. In this case, when the pulsewidth of the laser beam LB2 is increased as described above, while the SPM influence is reduced particularly in the last-stage optical fiber amplifier 25, the SBS (stimulated brillouin scattering) influence is increased. Nevertheless, however, bleaching of the gain occurs in the last-stage optical fiber amplifier 25. Hence, as shown by a solid line of waveform 29A in Fig. ~~7(c)~~ 7C, the pulsewidth of the laser beam LB3 output from the optical amplifier unit 18 is reduced shorter than that of a waveform 29B that is shown by a dotted line and that corresponds as is to the laser beam LB2. Thereby, the adverse effect of the pulsewidth expanded in the optical modulating device 12 is reduced; and consequently, the wavelengths-in-width of ultraviolet lights to be finally output overall can be narrowed.

Page 52, lines 21-27 and Page 53, lines 1-13:

In the above-described embodiment, the laser light source having an oscillation wavelength of about 1.544 μm is used for the single wavelength oscillatory laser 11. Instead of this laser light source, however, the embodiment may use a laser light source having an oscillation wavelength in a range of from 1.099 to 1.106 μm. For this laser light source, either a DFB semiconductor laser or an ytterbium(Yb)-doped fiber laser may be used. In this case, for the optical fiber amplifier in the rear-stage optical amplification section, the configuration may use an ytterbium(Yb)-doped fiber (YDFA) that performs amplification in

a wavelength zone of 990 to 1200 nm including the wavelength of the amplifier section. In this case, ultraviolet light having a wavelength of 157 to 158 nm wave that is substantially the same wavelength of the F_2 laser can be obtained by outputting the seventh-order harmonic wave in the wavelength conversion section 20 shown in Fig. ~~1(b)~~ 1B. In practice, ultraviolet light having substantially the same wavelength as that of the F_2 laser can be obtained by controlling the oscillation wavelength to be about 1.1 μm.

Page 57, lines 17-20:

Hereinbelow, a description will be made regarding example configurations of the wavelength conversion section 20 used in the ultraviolet light generator of the embodiment shown in ~~Fig. 1~~ Figs. 1A and 1B.

Page 57, lines 21-27 and Page 58, lines 1-20:

Fig. ~~8(a)~~ 8A shows the wavelength conversion section 20 that is capable of obtaining the eighth-order harmonic wave through repetition of the second-order harmonic wave generation. In Fig. ~~8(a)~~ 8A, the fundamental wave of the laser beam LB4 having a wavelength of 1.544 μm (the frequency is represented by "ω") output from an output terminal 19a of an optical fiber bundle 19 is incident on a first-stage nonlinear optical crystal 502. The second-order harmonic wave generation is performed therein to generate the second-order harmonic wave having a twofold frequency 2ω (wavelength: 1/2 of 772 nm) of the frequency ω. The generated second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 503 through a lens 505. Similar to the above, through the second-order harmonic wave generation, there is generated fourth-order harmonic wave having a twofold frequency of the frequency 2ω of the incident wave, that is, a fourfold frequency 4ω (wavelength: 1/4 of 386 nm) with respect to the fundamental wave. The generated fourth-

order harmonic wave is then transferred to a third-stage nonlinear optical crystal 504 through a lens 506. Similarly, through the second-order harmonic wave generation, there is generated eighth-order harmonic wave having a twofold frequency of the frequency 4ω of the incident wave, that is, an eightfold frequency 8ω (wavelength: 1/8 of 193 nm) with respect to the fundamental wave. The eighth-order harmonic wave is output as laser beam LB5. Thus, the example configuration performs wavelength modulations in the following order: fundamental wave (wavelength: 1.544 μm) → second-order harmonic wave (wavelength: 772 nm) → fourth-order harmonic wave (wavelength: 386 nm) → eighth-order harmonic wave (wavelength: 193 nm).

Page 59, lines 20-27 and Page 60, lines 1-5:

Referring to Fig. ~~8(a)~~ 8A, a converging lens, which is effective for improving the incidence efficiency of laser beam LB4, is preferably provided between the fiber bundle 19 and the nonlinear optical crystal 502. In this case, each of the optical fibers constituting the fiber bundle 19 has a mode diameter (core diameter) of about 20 μm, and a region where the conversion efficiency in the nonlinear optical crystal has a size of about 200 μm. As such, a lens with a very low magnification of about 10× magnification may be provided in units of the optical fiber to converge the laser beam output from each of the optical fibers into the nonlinear optical crystal 502. This applies also to other example configurations described below.

Page 60, lines 6-25:

Fig. ~~8(b)~~ 8B shows a wavelength conversion section 20A that is capable of obtaining the eighth-order harmonic wave by combining the second-order harmonic wave generation and sum frequency generation. Referring to Fig. ~~8(b)~~ 8B, the fundamental wave of the laser

beam LB4 having a wavelength of 1.544 μm output from the output terminal 19a of the fiber bundle 19 is incident on a first-stage nonlinear optical crystal 507 formed of the LBO crystal and controlled by the NCPM method. In the crystal 507, there is generated the second-order harmonic wave (wavelength: 722 nm) according to the second-order harmonic wave generation. In addition, a part of the fundamental wave is transmitted as is through the nonlinear optical crystal 507. Both the fundamental wave and second-order harmonic wave in a linearly polarized state are transmitted trough a wavelength plate 508 (for example, a 1/2 wavelength plate), and only the fundamental wave is output in a 90-degree rotated direction of polarization. The fundamental wave and the second-order harmonic wave individually pass through a lens 509 and are incident on a second-stage nonlinear optical crystal 510.

Page 63, lines 8-27:

The configuration between the second-stage nonlinear optical crystal 510 and the fourth-stage nonlinear optical crystal 517 is not limited to that shown in Fig. ~~8(b)~~ 8B. This configuration may be arbitrarily arranged as long as it has the same optical path lengths for the sixth-order harmonic wave and the second-order harmonic wave to cause the sixth-order harmonic wave and the second-order harmonic wave to be incident on the fourth-stage nonlinear optical crystal 517. Moreover, for example, the third-stage and fourth-stage nonlinear optical crystals 514 and 517 may be disposed on the same optical axis of the second-stage nonlinear optical crystal 510. In this configuration, the third-stage nonlinear optical crystal 514 is used to convert only the third-order harmonic wave into the sixth-order harmonic wave according to the second-order harmonic wave generation, and the converted harmonic wave and the non-converted second-order harmonic wave together may be incident on the fourth-stage nonlinear optical crystal 517. This configuration avoids the necessity of using the dichroic mirrors 511 and 516.

Page 64, lines 1-19:

For the individual wavelength conversion sections 20 and 20A shown in ~~Fig. 8(a) and (b)~~ Figs. 8A and 8B, the average output power of the per-channel eighth-order harmonic waves (wavelength: 193 nm) were experimentally obtained. As described in the above-described embodiment, the output of the fundamental wave at each of the channel output terminal is characterized by a peak power of 20 kW, a pulsewidth of 1 ns, a pulse repetition frequency of 100 kHz, and an average output power of 2W. As a result, the per-channel average output powers of the eighth-order harmonic waves were 229 mW in the wavelength conversion section 20 shown in Fig. ~~8(a)~~ 8A, and 38.3 mW in the wavelength conversion section 20A shown in Fig. ~~8(b)~~ 8B. Accordingly, the average output powers from the bundle of all the 128 channels are 29 W in the wavelength conversion section 20, and 4.9 W in the wavelength conversion section 20A. As such, in either of the wavelength conversion sections 20 and 20A, ultraviolet light having a wavelength of 193 nm beam, which is sufficient as an exposure-apparatus-dedicated light source can be provided.

Page 65, lines 18-27:

Hereinbelow, a description will be made regarding an example configuration of a wavelength modulator section that enables ultraviolet light having substantially the same wavelength as that of the F_2 laser (wavelength: 157 nm). To implement the above, as the wavelength conversion section 20, the configuration may be arranged to use a wavelength conversion section capable of generating the tenth-order harmonic wave with 1.57 μm wavelength of the fundamental wave generated in the single wavelength oscillatory laser 11 shown in Fig. ~~1(a)~~ 1A.

Page 66, lines 1-16:

Fig. ~~9(a)~~ 9A shows a wavelength conversion section 20B that enables the tenth-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. ~~9(b)~~ 9B, the fundamental wave of the laser beam LB4, having a wavelength of 1.57 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 602 formed of the LBO crystal, and is converted into the second-order harmonic wave according to the second-order harmonic wave generation. The second-order harmonic wave is then incident on a second-stage nonlinear optical crystal 604 formed of LBO via a lens 603, and is converted into the fourth-order harmonic wave according to the second-order harmonic wave generation; and a part of the second-order harmonic wave is transmitted therethrough without being converted.

Page 68, lines 18-27 and Page 69, lines 1-8

Fig. ~~9(b)~~ 9B shows a wavelength conversion section 20C that enables the seventh-order harmonic wave to be generated through combination of the second-order harmonic wave generation and the sum frequency generation. Referring to Fig. ~~9(b)~~ 9B, the laser beam LB4 (fundamental wave), having a wavelength of 1.099 μm, which has been output from the output terminal 19a of the fiber bundle 19, is incident on a first-stage nonlinear optical crystal 702 formed of the LBO crystal, and the second-order harmonic wave is generated therein according to the second-order harmonic wave generation. A part of the fundamental wave is transmitted as is therethrough. Both the fundamental wave and second-order harmonic wave transmits in a linearly polarized state transmits through a wavelength plate 703 (such as a 1/2 wavelength plate), and only the direction of polarization of only the fundamental wave is rotated through 90 degrees. The fundamental wave and the second-order harmonic wave is

led through a lens 704 to be incident on a second nonlinear optical crystal 705 formed of the LBO crystal. The third-order harmonic wave is generated therein according to the sum frequency generation, and a part of the second-order harmonic wave is transmitted as is therethrough.

Page 70, lines 23-27 and Page 71, lines 1-14:

As is apparent from Fig. ~~1(a)~~ 1A, in the above-described embodiment, the combined light of the outputs of the n optical amplifier units 18-1 to 18-n in the m-group is converted in wavelength by using the single wavelength conversion section 20. Alternatively, however, the configuration may be arranged such that, for example, m' units (m' = "2" or larger inger) wavelength conversion sections are provided. In the alternative configuration, the outputs of the m-group optical amplifier units 18-1 to 18-n are divided in units of n' outputs into m' groups, the wavelength conversion is performed for one of the wavelength conversion section in units of one of the groups, and the obtained m' ultraviolet light beams (in the present example, m' = "4", "5", or the like) are combined. Thus, the wavelength conversion section 20 is not limited to that having the above-described configuration. Moreover, for example, a CBO crystal (CsB_3O_5), a lithium tetraborate $Li_2B_4O_7$ (LBO), a KAB ($K_2Al_2B_4O_7$), or a GdYCOB ($Gd_XY_{1-x}Ca_4O(BO_3)_3$), may be used as an alternative crystal for the nonlinear optical crystal.

Page 71, lines 15-27 and Page 72, lines 1-3:

According to the ultraviolet light generator of the above-described embodiment, the diameter of the output terminal of the fiber bundle 19, shown in Fig. ~~1(a)~~ 1A, even with all the channels being included, is about 2 mm or smaller. As such, one or several units of the wavelength conversion sections 20 are sufficient to perform the wavelength conversion of all

the channels. In addition, since flexible optical fibers are used for the output terminals, the flexibility in configuration is very high. For example, the configuration sections such as the wavelength conversion section, the single wavelength oscillatory laser, and the splitter, can be separately disposed. Consequently, the ultraviolet light generator of the present example enables the provision of an ultraviolet laser device that is inexpensive and compact, and has a low spatial coherence while it is of a single wavelength type.

Page 72, lines 4-26:

Hereinbelow, an example exposure apparatus using the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A will be described. Fig. 10 shows the exposure apparatus of the present example. Referring to Fig. 10, devices usable for an exposure light source 161 include, for example, a device with an ultraviolet region of 193 nm, 157 nm, or the like based on the wavelength of a laser beam that is output from the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A. A laser beam LB5 that has been output from the exposure light source 161 is incident as exposure light IL on an illumination system 162. The illumination system 162 is configured of, for example, an optical integrator (homogenizer) for homogenizing illuminance distributions of the exposure light IL, an aperture diaphragm, a field diaphragm (reticle blind), and a condenser lens. In the aforementioned configuration, the exposure light IL output from the illumination system 162 illuminates a slit-like illumination region of a pattern surface of a reticle 163 set as a mask to provide a homogeneous illuminance distribution. In the present example, since the spatial coherence of the exposure light IL is so low that the configuration of a member for reducing the spatial coherence in the illumination system 162 can be simplified, and the exposure apparatus can therefore be further miniaturized.

Page 74, lines 22-27 and Page 75, lines 1-19:

Exposure-light-amount control in the above-described scan-exposure operation may be implemented in the following manner. Control is performed for at least one of the pulse repetition frequency f, which is defined by the optical modulating device 12 shown in Fig. ~~1(a)~~ 1A, and the interchannel delay time, which is defined by the delaying devices (optical fibers 15-1 to 15-m, and 17-1 to 17-n). The control is thus performed to cause a fundamental-wave generator section 171 to oscillate a plurality of pulsed beams at equal time intervals during scan-exposure operation. In addition, according to the sensitivity property of the photoresist, at least one of the optical intensity of the pulsed beam on the wafer 166, the scan speed for the wafer 166, the pulsed-beam oscillation interval (frequency), and the width of the pulsed beam in the scan direction for the wafer 166 (that is, an radiation region thereof) to thereby control the integrated luminous quantity of a plurality of pulsed beams irradiated in a period in which the individual points of the wafer traverse the radiation region. At this time, in consideration of the throughput, least one of other control parameters representing the pulsed-beam optical intensity, the oscillation frequency, and the radiation region width is preferably controlled so that the scan speed for the wafer 166 is substantially maintained to be the maximum speed of the wafer stage 167.

Page 75, lines 20-27 and Page 76, lines 1-8:

Fig. 11 shows another exposure apparatus using the ultraviolet light generator of the present example. Referring to Fig. 11, the ultraviolet light generator shown in Fig. ~~1(a)~~ 1A is attached apart. Specifically, referring to Fig. 11 showing the portions corresponding to those shown in Fig. 10 by assigning the same reference symbols, a wavelength conversion section 172 corresponding to the wavelength conversion section 20 shown in Fig. ~~1(a)~~ 1A is mounted on the exposure apparatus mainbody. On the other hand, a light-source mainbody section

171 corresponding to the members of from the single wavelength oscillatory laser 11 to optical splitting amplifier section 4 shown in Fig. ~~1(a)~~ 1A are provided outside of the exposure apparatus mainbody, and a coupling-dedicated optical fiber 173 is used to couple therebetween. The coupling-dedicated optical fiber 173 corresponds to the fiber bundle 19 shown in Fig. ~~1(a)~~ 1A.

Page 78, lines 8-18:

In the present example, a laser beam from the light-source mainbody section 171 is fed to a wavelength conversion section 179 via an optical fiber 178. For the wavelength conversion section 179, the present example uses a wavelength conversion section that is similar to the wavelength conversion section 20 shown in Fig. ~~1(a)~~ 1A and that is relatively small. The wavelength conversion section 179 is integrally provided on the frame that holds the alignment system 180, in which ultraviolet light that has been output from the wavelength conversion section 179 is used as illumination light.

Page 79, lines 9-25:

The exposure apparatus of the above-described embodiment shown, for example, in Fig. 11, may include a spatial-image measuring system. The spatial-image measuring system may be such that the mark provided on the reticle 163 and the reference mark provided on the reticle stage 164 are illuminated with illumination light having the same wavelength, and a mark image formed by the projection optical system 165 is detected through an opening (such as a slit) provided on the wafer stage 167. For a light source generating the illumination light for the spatial-image measuring system, a light source (similar to the ultraviolet light generator shown in ~~Fig. 1~~ Figs. 1A and 1B) having the same configuration as that of the above-described light source (171 and 179) may be separately provided. Alternatively, the

exposure-dedicated light source formed of the members including the light-source mainbody section 171 and the illumination system 162 may be shared.

Page 79, lines 26-27 and Page 80, lines 1-10:

In the above-described embodiment, description has been made that the laser device shown in ~~Fig. 1~~ Figs. 1A and 1B is used either as the exposure-dedicated light source or as the light source of the alignment system or the spatial-image measuring system. However, the laser device may be used as a regulating light source of a detecting system or an optical system for marks other than the above. In addition, the laser device may be used not only as the light source of the exposure apparatus, the testing apparatus, or the like used in the device-manufacturing step, but also as a light source of various other apparatuses, regardless of the use and like thereof (an example is an apparatus using an excimer laser as a light source, such as a laser medical treatment apparatus for performing medical treatment for, for example, the near site and the astigmatism, by correcting, for example, the curvature or the irregularity of the cornea).

Changes to Claims:

The following is a marked-up version of the amended claims:

1. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, and a narrow band filter and an isolator disposed between the plural stages of the optical fiber amplifiers; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

2. (Amended) An exposure apparatus as recited in claim 1, ~~characterized in that~~ wherein

the laser device includes an excitation-light generating light source which generating excitation light which is to be used at at least one of the plural stages of the optical fiber amplifiers, and the optical amplifier is formed such that a reflection film which reflects the excitation light is formed at one end of the optical fiber coupled to the narrow band filter.

3. (Amended) An exposure apparatus as recited in claim 1, ~~characterized in that~~ wherein

the narrow band filter and the isolator reduce noise of a wavelength corresponding to a phonon sideband.

4. (Amended) An exposure apparatus as recited in claim 1, ~~characterized in that~~ wherein

at least three stages of the optical fiber amplifiers are provided, and the narrow band filter and the isolator are respectively provided between the individual optical fiber amplifiers.

5. (Amended) An exposure apparatus as recited in claim 1, ~~characterized in that~~ wherein

a gate device, which performs timewise removal of ASE (amplified spontaneous emission), is further provided between the plural stages of the optical fiber amplifiers.

6. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of amplifying optical fibers which serially amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates excitation light for at least one stage of the amplifying optical fiber of the plural stages of the amplifying optical fibers, a narrow band filter or an isolator disposed between the plural stages of the amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

7. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, a plurality of excitation-light generating light sources which individually generate excitation lights for each of the plural stages of the optical fiber amplifiers, and a narrow band filter disposed between the plural stages of the optical fiber amplifiers, wherein a reflection film which reflects the excitation light is formed at one end of each of the optical fibers coupled to both sides of the narrow band filter; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

8. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical modulation section which modulates the laser light generated by the laser light generation section with a predetermined repetition frequency into pulsed light having a predetermined width;

an optical amplification section including an optical fiber amplifier which amplifies the laser light which has passed through the optical modulation section; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal, wherein

the width of the pulsed light modulated by the optical modulation section is set wider than a pulsewidth set for obtaining a predetermined wavelength width with finally generated ultraviolet light.

9. (Amended) An exposure apparatus as recited in claim 8, ~~characterized in that~~ wherein the width of the pulsed light modulated by the optical modulation section is 2 to 5 ns.

10. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including an optical fiber amplifier which amplifies the laser light generated by the laser light generation section, a transmitting optical fiber which propagates the laser light amplified by the optical fiber amplifier, and a narrow band filter disposed between the optical fiber amplifier and the transmitting optical fiber; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

11. (Amended) An exposure apparatus as recited in claim 10, ~~characterized in that~~ wherein the narrow band filter is concurrently used as a wavelength division multiplexing device for multiplexing which feeds excitation light to the optical fiber amplifier.

12. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1, ~~6, 7, 10 and 11,~~ ~~characterized in that~~ wherein

the laser device includes an optical modulation section which modulates the laser light generated by the laser light generation section into pulsed light and which sets the width of the pulsed light to be wider than a pulsewidth set for obtaining a predetermined wavelength width with the ultraviolet light.

13. (Amended) An exposure apparatus as recited in claim 12, ~~characterized in that~~ wherein

the laser device includes an optical splitter which splits the laser light generated by the laser light generation section into a plurality of laser light beams, the optical amplification section is independently provided for each of the plural split laser light beams, and

the laser device further includes a regulator which regulates an amplification gain of the optical amplification sections so that outputs of the plurality of split laser light beams are substantially uniformalized.

14. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11~~, ~~characterized in that~~ wherein the optical fiber amplification section is an erbium-doped fiber amplifier and uses laser light having a wavelength of (980±10) nm as the excitation light for the amplifier.

15. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 8, 10 and 11~~, ~~characterized by using~~ wherein a multilayer film filter or a fiber Bragg grating is used for the narrow band filter.

16. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11~~, ~~characterized in that~~ wherein the laser light generation section includes a single wavelength oscillatory laser which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, and an oscillation-wavelength control means which controls an oscillation wavelength of the generated laser light to be a predetermined wavelength.

17. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11~~, ~~characterized in that~~ wherein

the laser device further includes an optical splitter which splits the laser light generated by the laser light generation section into a plurality of laser light beams,

the optical amplification section is independently provided for each of the plural split laser light beams, and

the wavelength conversion section performs collective wavelength conversion of a bundle of the laser light beams output from the plural optical amplification sections.

18. (Amended) An exposure apparatus as recited in claim 17, ~~characterized by~~ further comprising a regulator which regulates an amplification gain of the optical amplification sections so that outputs of the plurality of split laser light beams are substantially uniformalized.

19. (Amended) An exposure apparatus as recited in claim 17, ~~characterized in that~~ wherein the regulator changes the output of the excitation light used for the optical fiber amplifier in the optical amplification section.

20. (Amended) An exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, ~~characterized in that~~ wherein

the laser device includes:

a laser generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, an optical splitter which splits the laser light into a plurality of laser light beams, a plurality of optical fiber amplifiers which respectively and independently amplify the plurality of split laser light beams, a wavelength conversion section which performs wavelength conversion of the amplified laser light beams, and

the laser device includes a regulator which regulates an amplification gain at at least one of the plurality of the optical fiber amplifiers so that outputs of the plurality of split laser light beams are substantially uniformalized.

21. (Amended) An exposure apparatus as recited in claim 20, ~~characterized in that~~ wherein the regulator controls an excitation-light generating light source which generates excitation light used in the at least one optical fiber amplifier.

22. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized in that~~ wherein

the laser light generation section generates single wavelength laser light having a wavelength of near 1.5 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.5 μm into ultraviolet light of an eighth-order harmonic wave or a tenth-order harmonic wave and outputs the converted light.

23. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized in that~~ wherein

the laser light generation section generates a single wavelength laser light having a wavelength of near 1.1 μm, and

the wavelength conversion section converts a fundamental wave output from the optical amplification section having a wavelength of near 1.1 μm into ultraviolet light of a seventh-order harmonic wave thereof and outputs the converted light.

24. (Amended) An exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized by~~ comprising:

an illumination system which radiates ultraviolet light from the laser device onto a mask as the first object: and

a projection optical system which projects an image of a pattern of the mask onto a substrate as the second object.

25. (Amended) An exposure method using an exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~, ~~characterized in that~~ comprising using the ultraviolet light output from the laser device ~~is used~~ to perform alignment between the first object and the second object.

26. (Amended) A method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and that expose a second object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ comprising configuring the laser device ~~is configured~~ by disposing, with a predetermined relationship,

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region,

an optical amplification section including plural stages of optical fiber amplifiers which serially amplify the laser light generated by the laser light generation section, and a narrow band filter and an isolator disposed between the plural stages of the optical fiber amplifiers, and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

27. (Amended) A method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which exposes a second

object with the ultraviolet light which has passed through the pattern of the first object, ~~characterized in that~~ comprising configuring the laser device ~~is configured~~ by disposing, with a predetermined relationship,

a laser light generation section which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region;

an optical amplification section including plural stages of amplifying optical fibers which serially amplify the laser light generated by the laser light generation section, an excitation-light generating light source which generates excitation light for at least one stage of the amplifying optical fiber of the plural stages of the amplifying optical fibers, a narrow band filter or an isolator disposed between the plural stages of the amplifying optical fibers, and a bypass member which passes the excitation light in parallel to the narrow band filter or the isolator; and

a wavelength conversion section which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

28. (Amended) A device manufacturing method ~~which includes~~ including ~~a step of~~ transferring a mask pattern onto a substrate by using the exposure apparatus as recited in ~~any one of~~ claims 1 ~~to 11, 20 and 21~~.

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10/070682

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Tomoko OHTSUKI

Application No.: 10/070,682

Filed: September 4, 2002 Docket No.: 112161

For: EXPOSURE APPARATUS WITH LASER DEVICE

REQUEST FOR APPROVAL OF DRAWING CORRECTION(S)

Director of the U.S. Patent and Trademark Office
Washington, D.C. 20231

Sir:

The Examiner is requested to review and approve the proposed corrections to Figures 1 and 7-9, marked in red on the attached copy of such drawing figures.

Upon approval by the Examiner, and upon allowance of this application, the formal drawings will be corrected.

Respectfully submitted,

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Date: September 4, 2002

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FIG.1A

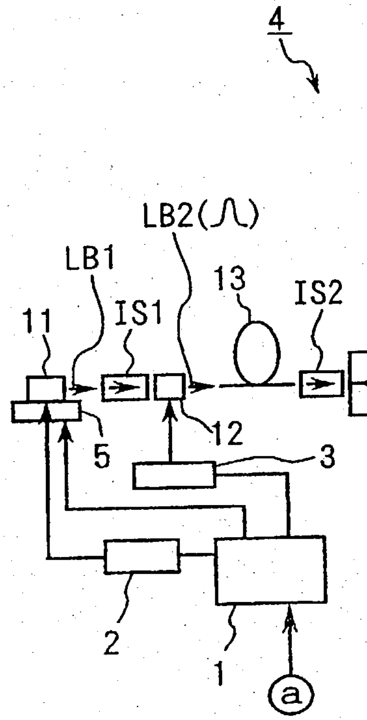
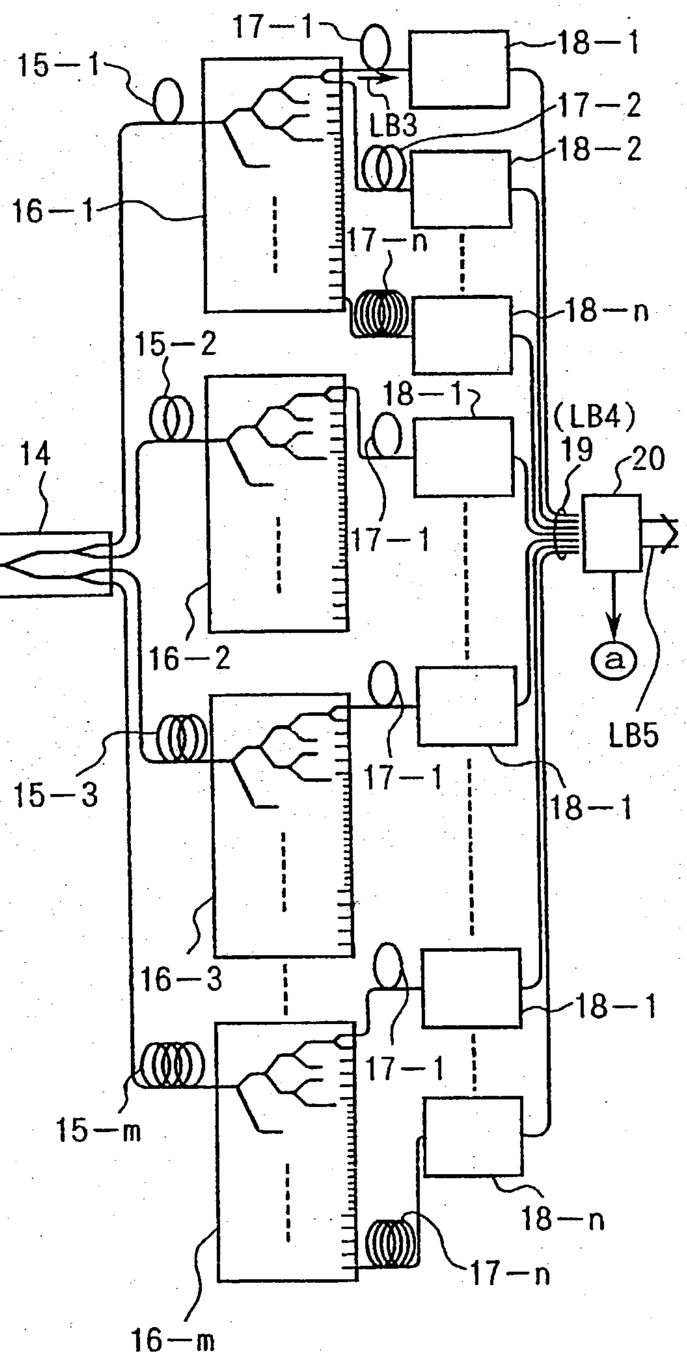


4
LB1
LB2
13
IS1
IS2
14
11
5
12
3
2
1
a
15—1
15—2
15—3
15—m
16—1
16—2
16—3
16—m
17—1
17—2
17—n
18—1
18—2
18—n
LB3
(LB4)
19
20
LB5

FIG.1B

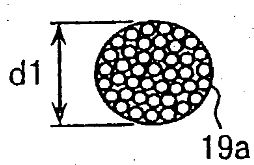

d1
19a

FIG.7A

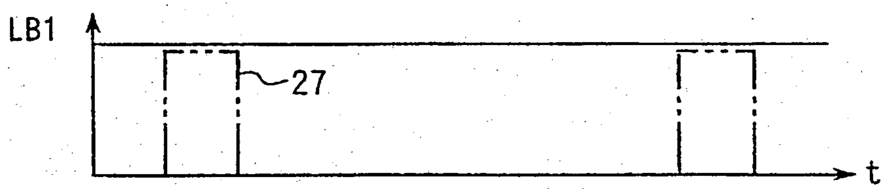


FIG.7B

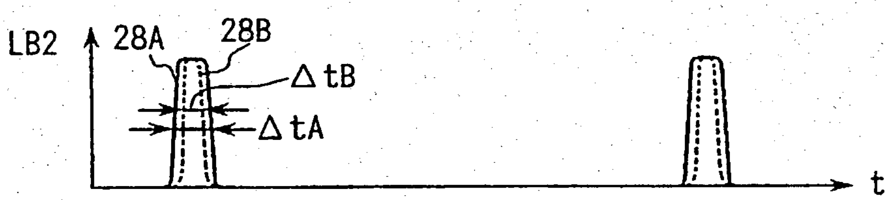


FIG.7C

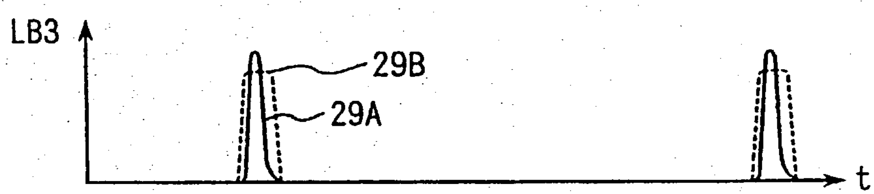


FIG.8A

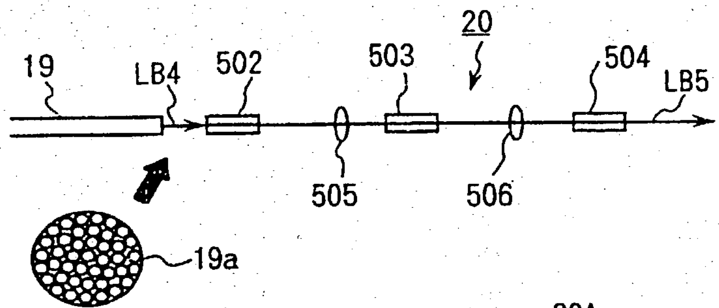


FIG.8B

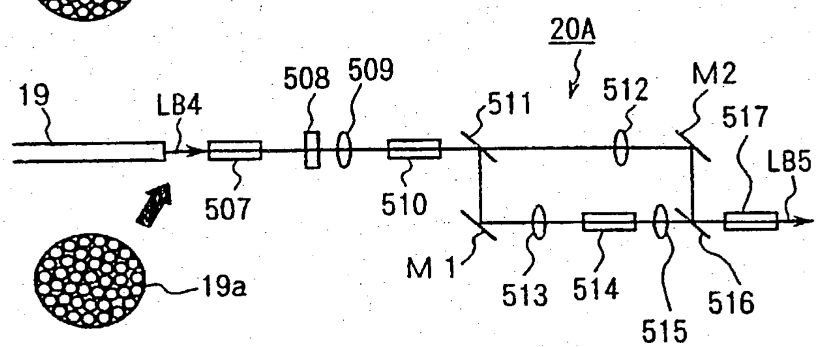


FIG.9A

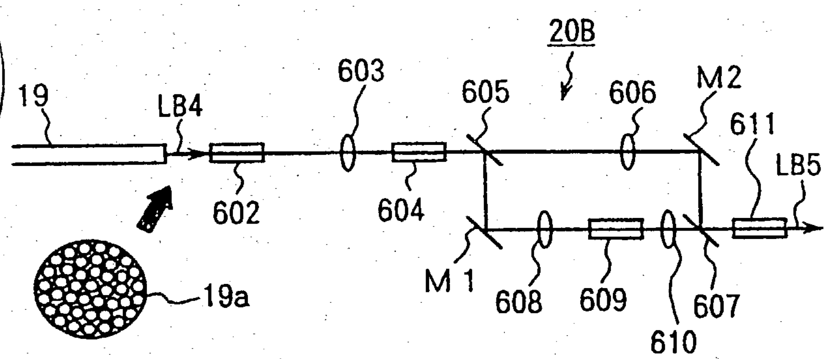
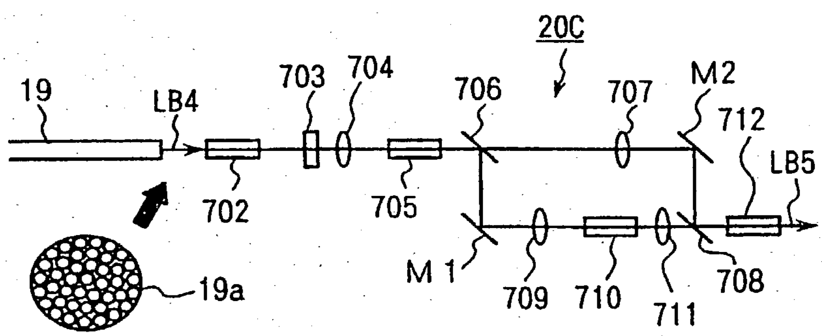


FIG.9B



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#4

DESCRIPTION

EXPOSURE APPARATUS WITH LASER DEVICE

Technical Field

The present invention relates to an exposure apparatus including a laser device which generates ultraviolet light. More specifically, the present invention is preferably used as an exposure apparatus used in a photolithography process for manufacturing microdevices, such as semiconductor devices, image pickup devices (such as CCDs), liquid crystal display devices, plasma display devices, and thin-film magnetic heads.

Background Art

For example, an exposure apparatus used in a photolithography process for manufacturing a semiconductor integrated circuit optically reduces and projectively exposes a circuit pattern accurately rendered on a reticle (photomask) used as a mask, onto the photoresist-coated surface of a wafer as a substrate. In the exposure, shortening of an exposure-light wavelength (exposure wavelength) is one of the most simple and effective methods to reduce the minimum pattern size (resolution) on the wafer. Hereinbelow, a description will be made regarding conditions

that should be provided to configure an exposure light source, in addition to those for the implementation of the wavelength shortening of the exposure-light.

First, for example, an optical output of several watts is required. The optical output is required to reduce time necessary for exposure and transfer of an integrate circuit pattern and thereby to increase a throughput.

Second, when the exposure light is ultraviolet light having a wavelength of 300 nm or shorter, an optical material which can be used for a reflector member (lens) of a projection optical system is limited, and hence the difficulty increases for compensation of the chromatic aberration. For this reason, monochromaticity of the exposure light is required, and the spectral linewidth needs to be controlled to be about 1 pm or less.

Third, the timelike coherence increases in association with the reduction in the spectral linewidth. As such, when light having a narrow spectral linewidth (wavelength width) is emitted as it is, an unnecessary interference pattern called "speckle" is generated. Therefore, in the exposure light source, the spatial coherence needs to be reduced to suppress generation of the speckles.

One of conventional short-wavelength light sources satisfying these conditions is a light source using an excimer laser in which the laser oscillation wavelength itself is a short wavelength. Another conventional short-wavelength light source is of a type using harmonic waves generation of

an infrared or visible-range laser.

A KrF excimer laser (having a wavelength of 248 nm) is used as the above-described former short-wavelength light source. Currently, an exposure light source using a shorter-wavelength ArF excimer laser (having a wavelength of 193 nm) is under development. In addition, a proposal has been made for use of an F_2 laser (having a wavelength of 157 nm), which is one of excimer lasers. However, these excimer lasers are of a large scale, and the oscillatory frequency thereof is at about a level of several kHz in a present stage. This requires a per-pulse energy to be increased to increase a per-unit-time radiation energy. This arises various problems. For example, the transmittance of an optical component tends to vary because of so-called compaction and the like, complicated maintenance is required and hence costs are increased.

As the aforementioned latter method, there is a method that uses a secondary nonlinear optical effect of a nonlinear optical crystal, and thereby converts long wavelength light (infrared light or visible light) into ultraviolet light of short wavelength. For example, a publication ("Longitudinally diode pumped continuous wave 3.5W green laser", L. Y. Liu, M. Oka, W. Wiechmann and S. Kubota; Optics Letters, vol. 19, p189(1994)) discloses a laser source that performs a wavelength conversion of light emitted from a solid-state laser excited by a semiconductor laser beam. The publication regarding the aforementioned conventional

example describes a method of performing a wavelength conversion for a 1,064 nm laser beam generated by an Nd:YAG laser by using a nonlinear optical crystal, and thereby generates light of a 4th-harmonic-wave of 266-nm. The solid-state laser is a generic name of lasers using a solid-state laser medium.

In addition, for example, Japanese Patent Application Laid-Open No. 8-334803 and corresponding United States Patent No. 5,838,709 proposed an array laser. The array laser is formed to include a plurality of laser elements in a matrix form (for example, a 10×10 matrix). Each of the laser elements is formed to include a laser-beam generating section including a semiconductor laser, and a wavelength conversion section for performing wavelength conversion for light emitted from the laser-beam generating section into ultraviolet light by using a nonlinear optical crystal.

The conventional array laser thus constituted enables an overall-device light output to be a high output while mitigating light outputs of the individual laser elements to be lower. This enables burden onto the individual nonlinear optical crystals to be lessened. On the other hand, however, since the individual laser elements are independent of one another, to apply the lasers to an exposure apparatus, oscillatory spectra of the overall laser elements need to be set identical with one another at the overall width up to a level of 1 pm.

For the above reason, for example, the length of a

resonator of each of the laser elements needs to be adjusted, or a wavelength-selecting device needs to be inserted into the resonator to cause the laser element to autonomously oscillate with the same wavelength in a single longitudinal mode. In this connection, these methods arises other problems. For example, the aforementioned adjustment requires a sensitive arrangement; and in proportion to the increase in the constituent laser elements, the complexity of the configuration needs to be increased to cause the overall devices to oscillate with the same wavelength.

On the other hand, known methods of actively unifying the wavelengths of the plurality of lasers include an injection seed method (for example, see, "Walter Koechner; Solid-state Laser Engineering, 3rd Edition, Springer Series in Optical Science, Vol.1, Springer-Verlag, ISBN 0-387-53756-2, pp.246-249"). According to this method, light from a single laser light source having a narrow spectral linewidth is split into a plurality of laser elements, and the laser beams are used as induction waves to tune the individual laser elements, and in addition, to causes the spectral linewidths to be narrow bandwidths. However, the method has problems in that it requires an optical system for separating the seed light into the individual laser elements and an oscillatory-wavelength tuning control section, thereby increase complexity of the configuration.

In addition, the array laser as described above enables the overall device to be significantly smaller than that with

the conventional excimer laser, it still causes difficulty in packaging so as to reduce the diameter of overall arrayed output beams to several centimeters or smaller. The array laser thus configured has additional problems. For example, each of the arrays requires the wavelength modulator section, thereby increasing the cost. In addition, suppose misalignment has occurred in a part of the laser elements constituting the array, or damage has occurred with the constituent optical elements. In this case, the overall array needs to be once disassembled, the defective part of the laser elements needs to be taken out for repair, and the array needs to be reassembled after repair.

The light source may possibly be configured using optical fibers. However, when light having a high intensity is propagated by simply using the optical fibers, problems can occur in that the wavelength width of the propagated light expands because of the influence of various factors attributed to nonlinear effects of the optical fibers. The factors include self phase modulation (hereinafter will be referred to as "SPM"), stimulated raman scattering (hereinafter will be referred to as "SRS") and stimulated brillouin scattering (hereinafter will be referred to as "SBS"). The wavelength width thus expanded reduces the margin for controlling the spectral linewidth of the exposure light to be 1 pm or less.

In view of the above, a primary object of the present invention is to provide an exposure apparatus including a laser device that can be used for a light source of the exposure

apparatus, that enables the exposure apparatus to be miniaturized, and that enables the maintainability to be enhanced.

A second object of the present invention is to provide an exposure apparatus including a laser device capable of suppressing the expansion of the wavelength width attributed to an nonlinear effect of a used optical element.

A third object of the present invention is to provide an exposure apparatus including a laser device which enables the oscillatory frequency to be increased, and enables the spatial coherence to be reduced, as well as enabling the overall oscillatory spectral linewidth to be narrowed with a simple configuration.

Additional object of the present invention is to provide an exposing method using the aforementioned exposure apparatus, a device-manufacturing method and an efficient manufacturing method of the aforementioned exposure apparatus.

Disclosure of the Invention

A first exposure apparatus of the present invention illuminates a pattern of a first object (163) with ultraviolet light from a laser device and exposes a second object (166) with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region

to a visible region; an optical amplification section (18) including plural stages of optical fiber amplifiers (22, 25) which serially amplifies the laser light generated by the laser light generation section, and a narrow band filter (24A) and an isolator (IS3) between the plural stages of the optical fiber amplifiers; and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

In this case, to perform timelike removal of ASE (amplified spontaneous emission), a device such as an acousto-optic modulator (AOM) or an electro-optic modulator (EOM) which functions as a gate that is to be turned on only when pulsed light passes through, may be inserted between the plural stages of the optical fiber amplifiers.

A second exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light output from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section (18A; 18B) including plural stages of amplifying optical fibers (22 and 25) which amplify the laser light generated by the laser light generation section, an excitation-light generating light source (23A) which generates a plurality of amplifying

excitation light beams, a narrow band filter (24A) or an isolator (IS3) disposed between the plurality of the amplifying optical fibers, and a bypass member (21B, 21C, and 30) which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

A third exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device includes a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section (18C) including plural stages of optical fiber amplifiers (22 and 25) which amplify the laser light generated by the laser light generation section, a plurality of excitation-light generating light sources (23A and 23D) which individually generate excitation light for each of the plural stages of the amplifying optical fibers, and a narrow band filter (24A), a reflection film which reflects the excitation light being formed at one of each of the optical fibers coupled to both sides of the narrow band filter; and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into

ultraviolet light by using a nonlinear optical crystal.

A fourth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical modulation section (12) which modulates the laser light generated by the laser light generation section with a predetermined repetition frequency into pulsed light having a predetermined width; an optical amplification section (18-1) including an optical fiber amplifier (22 and 25) which amplifies the laser light which has passed through the optical modulation section; and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal, the width of the pulsed light modulated by the optical modulation section is set wider than a pulsewidth set for obtaining a predetermined wavelength width with finally generated ultraviolet light.

A fifth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation

section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section (18D) including an optical fiber amplifier (25) which amplifies the laser light generated by the laser light generation section, a transmitting optical fiber (26) which propagates the laser light amplified by the optical fiber amplifier, and a narrow band filter (24A) disposed between the optical fiber amplifier and the transmitting optical fiber; and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

A sixth exposure apparatus of the present invention illuminates a pattern of a first object with ultraviolet light from a laser device and exposes a second object with the ultraviolet light which has passed through the first object, wherein the laser device includes a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, an optical splitter which splits the laser light into a plurality of laser light beams, a plurality of optical fiber amplifiers which respectively and independently amplify the plurality of split laser light beams, a wavelength conversion section (20) which performs wavelength conversion of the amplified laser light beams, and the laser device includes a regulator which regulates an amplification gain at at least

one of the plurality of the optical fiber amplifiers so that outputs of the plurality of amplified laser light beams are substantially uniformalized.

The exposure apparatus in each of the above-described aspects of the present invention allows use of a light source which is small and which has a narrow oscillatory spectrum such as, for example, a distributed feed back (DFB) semiconductor laser controlled in oscillation wavelength or a fiber laser as the laser light generation section in the laser device. High-output single wavelength ultraviolet light which has a narrow spectral width can be obtained in the following manner. Single wavelength laser light output from the laser light generation section is amplified using the plural stages of optical fiber amplifiers; and thereafter, the laser light is converted into ultraviolet light through the nonlinear optical crystal. As such, the present invention enables the provision of the exposure apparatus including the laser device which is small and which has high maintainability.

In this case, for example, one of the following amplifiers can be used for the optical fiber amplifier: an erbium(Er)-doped fiber amplifier(EDFA), a ytterbium(Yb)-doped fiber amplifier(YDFA), a praseodymium(Pr)-doped fiber amplifier(PDFA), and a thulium(Tm)-doped fiber amplifier (TDFA). However, when high-intensity light is propagated through the optical fiber amplifiers, an undesirable case can occur in which the wavelength width expands according to

nonlinear effects.

During the nonlinear effects working, the longer the fiber length, the wider the wavelength width expansion due to SPM (self phase modulation) and SRS (stimulated raman scattering). For example, in a simple model, the wavelength width expansion due to the SPM is proportional to the fiber length. Therefore, reducing the fiber length enables the wavelength width expansion due to the SPM to be mitigated. When an optical intensity at which the SPM begins to occur is used as an SRS threshold, the SRS threshold is inversely proportional to the fiber length. Therefore, effects of mitigating the wavelength width expansion in the output of the optical fiber amplifier can be obtained by reducing the fiber length to increase the SRS threshold and to thereby cause SRS not to easily occur. Thus, for either of the SPM and SRS, the wavelength width expansion can be reduced by reducing the fiber length.

Either the SRS or SBS (stimulated brillouin scattering) is a phenomenon in which light propagating through a fiber is caused by phonon to scatter into the phonon sideband. The wavelength of light caused to scatter into the phonon sideband expands in width with respect the original wavelength; specifically, the wavelength is expanded in width to be different from the original wavelength by the wavelength of the phonon. In addition, because of the SRS and SBS, the light scattered into the phonon sideband is amplified coherently, thereby increasing the intensity thereof. Particularly,

when noise of a wavelength equivalent to the phonon sideband exists, since the noise works as a seed (seed light) to cause amplification, the intensity of the scattering light is increased. This causes the influence of the wavelength width expansion due to the SRS and the SBS to be conspicuous. Accordingly, the noise working as the seed needs to be reduced to reduce the influence of the SRS and the SBS.

In consideration of the above, according to the above-described present invention, the narrow band filter and the isolator are inserted in the portion where the plural stages of optical fibers are coupled to thereby reduce the noise due to amplified spontaneous emission (which hereinbelow will be referred to as "ASE"). This enables the SRS and SBS to be reduced.

As another method, the ASE can also be reduced by inserting the isolator between the plural stages of optical fiber amplifiers. Thereby, the influence of the SRS and SBS can be reduced. In addition, by inserting the narrow band filter between the plural stages of optical fiber amplifiers, the ASE can be reduced, and light caused to scatter according to the Raman scattering can be blocked by the narrow band filter. Consequently, scattering light can be prevented from being amplified coherently, and the SRS influence is reduced.

In these cases, either the isolator or the narrow band filter prevents the excitation light from being propagated. As such, the bypass member is provided to allow the excitation light to propagate to the optical fiber amplifiers provided

forwardly and backwardly of the isolator or the narrow band filter. For the bypass members, the coupling-dedicated wavelength division multiplexing (WDM) devices are used. Thereby, the excitation light can be efficiently used.

In addition, the wavelength width expansion due to nonlinear effects can be reduced in a configuration in which optical fiber amplifiers having a two-way excitation construction are coupled and the narrow band filter is disposed in the coupled portions. Moreover, in a configuration where the film for reflecting the excitation light is formed on one end surface of the optical fibers coupled to both ends of the narrow band filter, the excitation light injected from both the front and rear sides are individually reflected thereby to cause the excitation light to reversely propagate and to return to the original optical fiber amplifiers. This avoids the necessity of providing, for example, WDM-dedicated multiplexers for the aforementioned excitation-light bypassing. Consequently, the configuration can be simplified, and the problem of WDM insertion loss can be avoided.

Furthermore, another method is usable. For the waveform of the pulsed light converted in the optical modulation section, the method uses a waveform having a width (for example, in a range of from 2 to 5 ns) that is several times longer than a pulsewidth for obtaining a predetermined wavelength width with the finally generated ultraviolet light, i.e., a pulsewidth which is determined depending on the

transfer limit in a required frequency width and that is controlled to maximize the pulse transient time. In this case, the pulsewidth of the output light is reduced by using bleaching of the gain in the optical fiber amplifier at the last stage.

Specifically, since the frequency expansion due to the SPM is proportional to timewise variations in optical intensity, the longer the pulse transient time in which the timewise variations in optical intensity are slow, the less the frequency expansion. As such, the SPM influence can be reduced by using a pulse of which transient time is long. On the other hand, a trade off occurs such that as the pulsewidth becomes wider, the SBS influence increases. In a simple model, the threshold of the optical intensity at which the SBS occurs is inversely proportional to the pulsewidth. However, the gain bleaching occurs in the last-stage optical fiber amplifier that is most problematic in SBS. As such, the pulsewidth of the output light is reduced, and the pulsewidth is wide, thereby reducing adverse effects.

In addition, still another method is usable. The method is such that to mitigate SRS propagation to the transmitting optical fiber from the high-output last-stage optical fiber, the narrow band filter is inserted in the coupled portion thereof. With the narrow band filter, the ASE can be reduced, the SRS propagation can be mitigated, and the wavelength width expansion of the propagated light can therefore be reduced.

For example, when an erbium-doped fiber amplifier

(EDFA) is used for the optical fiber amplifier, light having a wavelength of (980±10) nm or (1480 nm±30 nm) can be used as the excitation light. However, when the 980 nm band is used for the excitation light, the gain per unit length is higher than that when the 1480 nm band is used. As such, with the 980 nm band being applied, the fiber length can be reduced, and consequently, the ASE primarily causing noise can be reduced. That is, in comparison to the 1480 nm band excitation, the 980 nm band excitation enables noise by the optical fiber amplifier can be reduced lower.

A (970±10) nm light may be used as the excitation light for either an ytterbium(Yb)-doped fiber or an erbium/ytterbium-codoped fiber.

Preferably, each of the above-described laser devices is configured to further include an optical splitter (14, and 16-1 to 16-m) which splits the laser light generated by the laser light generation section into a plurality of laser light beams, and, in this configuration, optical amplification sections (18-1 to 18-n) are independently provided for the plurality of split laser beams respectively, and the wavelength conversion section collects fluxes of laser beams output from the plurality of optical amplification sections and performs wavelength conversion thereof. Thus, the laser light split by the optical splitters are sequentially imparted with predetermined differences in optical path lengths and therefore, the spatial coherence of the laser light finally bundled can be reduced. Moreover, since each of the laser

light beams is generated by the common laser light generation section, the spectral linewidth of the finally obtained ultraviolet light is narrow.

Further, the laser light can be modulated by a light modulator and the like at a high frequency of, for example, about 100 kHz. Moreover, each of the pulsed light beams is an aggregate of, for example, 100 pulses of light with predetermined time intervals. As such, in comparison to a case where an excimer laser light (having a wavelength of several kHz) is used, the pulse energy can be reduced to about 1/1000 to 1/10000 to obtain the same illuminance. Therefore, when the above-described laser device is used as an exposure light source, transmittance variations due to, for example, compaction, can substantially be eliminated, and stable and high-accuracy exposure can be implemented.

Concerning the configuration of the wavelength conversion section of the present invention, ultraviolet light formed of a harmonic wave having a frequency of an arbitrary integer multiple (a wavelength of an integer division of 1) with respect to that of the fundamental wave can be easily output through combination of second-order harmonic generation (SHG) by a plurality of nonlinear optical crystals and sum frequency generation (SFG).

For example, ultraviolet light substantially having the same wavelength of 193 to 194 nm as that of an ArF excimer laser can be obtained in a configuration in which a laser light whose wavelength is limited to 1.5 μm, particularly to a range

of from 1.544 to 1.552 μm is irradiated from the laser light generation section, and the eighth-order harmonic wave of the fundamental wave thereof is generated in the wavelength conversion section. Moreover, ultraviolet light substantially having the same wavelength of 157 to 158 nm as that of an F_2 laser can be obtained in a configuration in which laser light whose wavelength is limited to near 1.5 μm, particularly to a range of from 1.57 to 1.58 μm is irradiated from the laser light generation section, and the tenth-order harmonic wave of the fundamental wave thereof is generated in the wavelength conversion section. Similarly, ultraviolet light substantially having the same wavelength as that of an F_2 laser can be obtained in a configuration in which laser light whose wavelength is limited to near 1.1 μm, particularly to a range of from 1.099 to 1.106 μm is irradiated from the laser light generation section, and the seventh-order harmonic wave of the fundamental wave thereof is generated in the wavelength conversion section.

The exposure apparatus of the present invention further includes an illumination system (162) which irradiates a mask(163) with ultraviolet light from the laser device, and a projection optical system (165) which projects an image of a pattern of the mask onto a substrate (166), wherein the substrate is exposed with the ultraviolet light passed through the pattern of the mask. With the laser device of the present invention being used, the exposure apparatus can be miniaturized overall, and the maintainability thereof is

increased.

According to an exposing method of the present invention, the ultraviolet light from the laser device is used as alignment light for an exposure apparatus of, for example, a TTR (through the reticle) method type, of the exposure apparatus. The alignment light can be formed to substantially be continuous light, thereby facilitating the alignment.

Hereinbelow, a first exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object (163) with ultraviolet light from a laser device and which expose a second object (166) with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region, plural stages of optical fiber amplifiers (22 and 25) which serially amplify the laser light generated by the laser light generation section, an optical amplification section (18) including a narrow band filter (24A) and an isolator (IS3) between the plural stages of optical fiber amplifiers, and a wavelength conversion section (20) which performs wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

A second exposure apparatus manufacturing method according to the present invention is a method of manufacturing an exposure apparatus which illuminates a pattern of a first object with ultraviolet light from a laser device and which exposes a second object with the ultraviolet light which has passed through the pattern of the first object, wherein the laser device is configured by disposing with a predetermined relationship, a laser light generation section (11) which generates single wavelength laser light in a wavelength range of from an infrared region to a visible region; an optical amplification section (18A; 18B) including plurality of amplifying optical fibers (22 and 25) which amplify the laser light generated by the laser light generation section, an excitation-light generating light source (23A) which generates a plurality of amplifying excitation light beams, a narrow band filter (24A) or an isolator (IS3) disposed between the plurality of amplifying optical fibers, and a bypass member (21B, 21C, and 30) which passes the excitation light in parallel to the narrow band filter or the isolator; and a wavelength conversion section (20) for performing wavelength conversion of the laser light amplified by the optical amplification section into ultraviolet light by using a nonlinear optical crystal.

Furthermore, a device manufacturing method of the present invention includes a step of transferring a mask pattern onto a substrate by using the exposure apparatus of the present invention.

Brief Description of the Figures in the Drawings

Fig. 1 is a diagram showing an example of an ultraviolet light generator according to an embodiment of the present invention.

Fig. 2 is a diagram showing a first configuration example of optical amplifier units 18-1 to 18-n shown in Fig. 1.

Fig. 3 is a diagram showing a second configuration example of optical amplifier units 18-1 to 18-n.

Fig. 4 is a diagram showing a third configuration example of optical amplifier units 18-1 to 18-n.

Fig. 5 is a diagram showing a fourth configuration example of optical amplifier units 18-1 to 18-n.

Fig. 6 is a diagram showing a fifth configuration example of optical amplifier units 18-1 to 18-n.

Fig. 7 is a diagram showing waveforms of laser beams in individual portions of another example according to the present embodiment of the present invention.

In Fig. 8, Fig. 8(a) is a diagram showing a first configuration example of a wavelength conversion section 20 shown in Fig. 1, and Fig. 8(b) is a diagram showing a second configuration example of the wavelength conversion section 20.

In Fig. 9, Fig. 9(a) is a diagram showing a third configuration example of a wavelength conversion section 20,

and Fig. 9(b) is a diagram showing a fourth configuration example of the wavelength conversion section 20.

Fig. 10 is a configuration view showing an example of an exposure apparatus employing an ultraviolet light generator of the embodiment.

Fig. 11 is a configuration view showing another example of an exposure apparatus employing an ultraviolet light generator of the embodiment.

Best Mode for Carrying out the Invention

Hereinbelow, an example of a preferred embodiment according to the present invention will be described with reference to the accompanying drawings. The present example represents a configuration in which the present invention is applied to an ultraviolet light generator that can be used as a projection exposure apparatus such as a stepper method or a step-and-scan method, or as a light source for alignment and various tests.

Fig. 1(a) shows an ultraviolet light generator according to the present example. Referring to Fig. 1(a), a single wavelength oscillatory laser 11, which is provided as a laser light generation section, generates a laser beam LB1 that is formed of a continuous wave (CW) having a narrow spectral width and that has a wavelength of 1.544 μm. The laser beam LB1 is incident on an optical modulating device 12, which is provided as an optical modulator, via an isolator IS1 provided for blocking reverse light. The laser beam LB1

is converted therein into a laser beam LB2 (pulsed beam), and the laser beam LB2 is then incident on an optical splitting amplifier section 4.

The laser beam LB2 incident on the optical division amplifier section 4 passes through an optical fiber amplifier 13 provided as a front-stage optical amplification section, passes through the optical fiber amplifier 13, and is amplified therethrough. The amplified beam is then incident on a splitter 14 of a planar waveguide type provided as a first optical splitting device via an isolator IS2, and is then split into m laser beams each having the same optical intensity. The letter m represents integer "2" or a greater integer. In the present example, m = 4. For the optical fiber amplifier 13, the apparatus uses an erbium-doped fiber amplifier (EDFA) to amplify light having the same wavelength zone (which is near 1.544 μm in the present example) as that of the laser beam LB1, which generated by the single wavelength oscillatory laser 11. An excitation beam having a wavelength of 980 nm is fed into the optical fiber amplifier 13 via a coupling-dedicated wavelength division multiplexing device (not shown). Excitation beam having a wavelength of (980±10) nm or (1480 nm±30 nm) can be used for the erbium-doped fiber amplifier (EDFA). However, to prevent the increase in wavelength according to nonlinear effects, the (980±10) nm laser beam is preferably used as excitation beam to thereby reduce the fiber length. In comparison to the case where the light in the 1480 nm band, using the (980±10) nm excitation

beam is more preferable also in that noise can be reduced occurring in the optical fiber amplifier 13 because of amplified spontaneous emission (ASE). The above is the same for a rear-stage optical fiber amplifier.

The m laser beams that have been output from the splitter 14 are incident on planar-waveguide-type splitters 16-1, 16-2, …, and 16-m individually provided as second optical splitting devices via respective optical fibers 15-1, 15-2, …, and 15-m each having a different length. Thereby, the m laser beams are each split into n laser beams each having substantially the same optical intensity. The letter n represents "2" or a greater integer; and n = 32 in the present example. The first optical splitting device (14) and the second optical splitting devices (16-1 to 16-m) correspond to optical splitters of the present embodiment according to the present invention. Consequently, the laser beam LB1 emitted from the single wavelength oscillatory laser 11 is split overall into n·m laser beams (that is, 128 laser beams in the present example).

N laser beams LB3 output from the splitter 16-1 are incident on optical amplifier units 18-1, 18-2, …, and 18-n, individually provided as rear-stage optical amplification sections, via respective optical fibers 17-1, 17-2, …, and 17-n each having a different length; and the incident beams are amplified therethrough. The optical amplifier units 18-1 to 18-n each amplify a laser beam having the same wavelength zone (near 1.544 μm in the present example) as that of the

laser beam LB1 generated by the single wavelength oscillatory laser 11. Similar to the above, n laser beams output from the other splitter 16-2 to 16-m are incident on optical amplifier units 18-1 to 18-n, individually provided as the rear-stage optical amplification sections, via respective optical fibers 17-1 to 17-n each having a different length; and the incident beams are amplified therethrough.

The laser beams amplified by the m-group optical amplifier units 18-1 to 18-n propagate through extended portions of output terminals of optical fibers (described below) doped with a predetermined matter in the respective optical amplifier units 18-1 to 18-n. The aforementioned extended portions form a fiber bundle 19. The lengths of the m-group n optical fibers forming the fiber bundle 19 are identical to one another. However, the configuration may be such that the fiber bundle 19 is formed bundling, and the laser beams amplified by the optical amplifier units 18-1 to 18-n are transferred to the corresponding optical fibers. Thus, the optical splitting amplifier unit 4 is configured to include the members provided between the optical fiber amplifier 13 and the fiber bundle 19.

Laser beams LB4 having been output from the fiber bundle 19 are incident on a wavelength conversion section 20 including a nonlinear optical device, and is converted thereby into laser beams LB5 each formed of ultraviolet light. The laser beams LB5 are output to the outside as alignment light or testing light. As described above, the m-group optical